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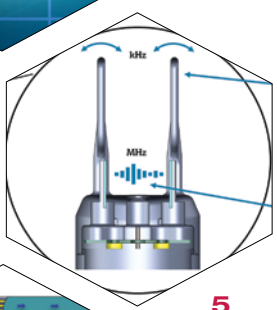

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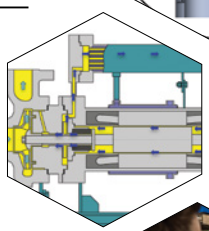
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Editor's Page

'Green' chemistry award winners

Now in its 27th year, the Green Chemistry Challenge Awards recognize and promote chemical technologies that reduce hazards to people and the environment by incorporating the principles of green chemistry into chemical design, manufacture and use. The program is sponsored by the U.S. Environmental Protection Agency's (EPA; www.epa.gov) Office of Chemical Safety and Pollution Prevention, in partnership with the American Chemical Society Green Chemistry Institute (ACS; www.acs.org), along with other members of the chemical community. Since 1996 there have been a total of 139 winners, including the following six outstanding achievements that are the recently announced 2023 winners (Source: EPA):

Greener Synthetic Pathways — **Solugen** (www.solugen.com) was recognized for its novel bio-based manufacturing platform, Bioforge. This first-of-its-kind chemoenzymatic manufacturing process has three primary steps comprising a cell-free enzymatic reactor, a metal reactor and an evaporator, which uses mechanical vapor recompression technology powered by wind energy. The process is said to be able to handle complex syntheses such as those in fermentation, but is not limited to the conditions required by living microbes.

Greener Reaction Conditions — This award went to **Captis Aire LLC** (www.captisaire.com) for its patent-pending CAIRE technology that converts terpenes into useful products. Terpenes are a waste product from wood manufacturing processes that are typically burned for fuel value. The award-winning technology captures the terpenes and converts them into a useable form for further processing, such as for biofuels, flavors and fragrances. The process was successfully demonstrated at three commercial wood-product manufacturing facilities.

Design of Greener Chemicals — **The Clorox Company** (www.thecloroxcompany.com) received this award for developing a disinfecting cleaner that can be used without personal protective equipment, does not bleach surfaces and contains no alcohol. Clorox EcoClean uses lactic acid as the active ingredient. The patented formula overcomes previous limitations in the use of lactic acid as a disinfectant.

Small Business — This award recognizes **Modern Meadow** (www.modernmeadow.com) for its textile dyeing process that is said to use 95% less water, 75% less energy and 80% fewer dyes and chemicals compared to traditional dyeing methods. The process, called BioFREED (Fast Resource Efficient Enhanced Dyeing) does not require a separate step to fix the dye and requires one or no washes at the end of the process, compared to 4–7 washes for traditional dyeing processes.

Academic Category — This honor was awarded to **Professor Richard Laine** from the University of Michigan (www.umich.edu) for developing a method to process rice hull ash — ash that results from burning the agricultural waste material rice hulls — into spirosiloxane that can be used to produce products, such as lithium-ion conducting polymers with potential use in solid-state batteries.

Specific Environmental Benefit: Climate Change — **Air Company** (www.aircompany.com) was recognized for its carbon dioxide removal technology that reacts CO_2 captured from industrial plants with "green" hydrogen produced by electrolysis, to manufacture numerous products, including methanol, ethanol and other compounds for fuels.

More details about the award process and the winners can be found on the EPA's website, as well as the individual company websites. ■

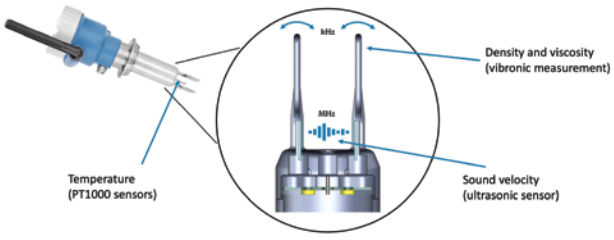
Dorothy Lozowski, Editorial Director

Monitor beer brewing 24/7 with this multisensor

In traditional beer brewing, the progress of the fermentation process is typically checked manually, by inserting a hydrometer (beer spindle) that measures the density, from which the extract content of the wort can be derived — a procedure that not only requires time, but also only gives a single measurement of the complex fermentation process at a point in time. To get a continuous view of the fermentation process in real time, Endress+Hauser (Reinach, Switzerland; www.endress.com) has developed a multisensory device that eliminates manual sampling, while providing details about every step of the process.

The QWX43 fermentation monitor (diagram) combines vibronic technology and ultrasound, as well as temperature, in a single sensor system, explained Julia Rosenheim, product owner GIL Innovation Lab at Endress+Hauser during an October 26 press event. The vibronic technology uses piezoelectric elements that cause the fork to oscillate. The frequency of the oscillation can be used to derive the density of the medium. Integrated into the piezoelectric elements is another sensor generating a high-frequency ultrasound signal between the forks. This signal is used to measure the concentration based on the acoustic speed. By intelligently linking the measured variables and incorporating empirically determined kinetic parameters, an algorithm automatically calculates — in real time — the alcohol content and the extract reduction. The same sensor can recognize the fermentation state of the process at any given time, as well as distinguish between fermentable and non-fermentable sugars in the wort before fermentation begins, Rosenheim said.

According to Rosenheim, the first version of the QWX43 fermentation monitor was launched in November 2021. Initially it could only communicate with the Endress+Hauser Netilion platform and could not be used directly for process control. "In this first version, we focused on process monitoring. In April 2023, we launched a version that communicates directly with the process control system. This version can be used directly for process control," she says.



Endress+Hauser

Making a proton-conducting membrane from waste feathers

Researchers at Eidgenössische Technische Hochschule Zürich (ETH Zurich; Switzerland; www.ethz.ch) and Nanyang Technological University Singapore (NTU; www.ntu.edu.sg) developed a process to utilize industrial chicken feathers for making proton-conductive membranes that can be used in fuel cells, protonic transistors and water-splitting electrolyzers. Unlike existing membranes, which are made from toxic "forever chemicals," the new membranes are based on the protein keratin, which accounts for 90 wt.% of feathers, an inexpensive and readily available resource. Each year, approximately 40 million metric tons of chicken feathers are incinerated. This not only releases large amounts of CO_2, but also produces toxic gases, such as sulfur dioxide.

As reported in a recent issue of *ACS Applied Materials & Interfaces*, the keratin is first extracted from feathers by a fast and economical process. The keratin is then converted into amyloid fibrils by a heat treatment, and further processed into membranes with an imparted proton conductivity of 6.3 mS/cm using a simple oxidative method. The functionality of the membranes was demonstrated by assembling them into a hydrogen fuel cell, in a water-splitting electrolyzer and in protonic field-effect transistors as thin-film modulators of protonic conductivity via the electrostatic gating effect.

The membrane manufactured in the laboratory is already up to three times less expensive than conventional membranes, according to ETH Zurich.

The researchers' next step will be to investigate how stable and durable their keratin membrane is, and to improve it if necessary. The research team has already filed a joint patent for the membrane and is now looking for investors or companies to develop the technology further and bring it to market.

Edited by:
Gerald Ondrey

LEATHER TANNING

Trumpler GmbH & Co. KG (Worms, Germany; www.trumpler.com) and Archroma (Pratteln, Switzerland; www.archroma.com) have developed a new leather-production process that can be used to produce high-performance leather in a more eco-friendly and cost-efficient way. The new process, DyTan, combines innovations from Archroma and Trumpler to offer an alternative to existing metal-free and chrome-tanned leather. It enables the reliable production of leather with "impeccable" shavability, excellent color depth and outstanding migration and abrasion resistance, the companies say. Free from metal salts and reactive aldehydes, DyTan is suitable for a wide range of leather applications, from garment and footwear to automotive and furniture upholstery.

At the core of the DyTan process is Archroma's patented Avicuero System, which enables collagen fibers in the leather to be covalently cross-linked through a simplified process at low temperatures. As a result, the system shows strong potential to save energy and water, while also reducing process time and CO_2 emissions by up to 23%. The DyTan process combines the Avicuero System with Trumpler's bio-based fatliquors and retanning agents based on functional biopolymers produced from hydrolyzed shavings — resource-saving technology that Trumpler has been refining for 15 years.

METHANOL

Toyo Engineering Corp. (Chiba, Japan; www.toyo-eng.com) and Cosmo Energy Holdings Co. (Tokyo, both Japan; www.cosmo-energy.co.jp) recently concluded a basic agreement regarding a joint study aimed

(Continues on p. 6)

at the direct synthesis of CO_2 into methanol using a catalyst. Toyo possesses a licensed technology called g-Methanol (Green Methanol), which enables direct synthesis of methanol from hydrogen and CO_2 separated and captured from petroleum refineries and plants. This is done in its proprietary MRF-Z reactor with multistage indirect cooling configuration. Since CO_2 can be used directly as a feedstock, it is expected that methanol can be produced efficiently without having to go through multiple processes.

BIOMETHANE

PT Perusahaan Gas Negara Tbk (PGN; Jakarta, Indonesia; www.pgn.co.id), a subsidiary of Indonesian national oil company PT Pertamina, and three Japanese companies — JGC Holdings Corp. (Yokohama; www.jgc.com), Osaka Gas Co. (www.osakagas.co.jp) and Inpex Corp. (Tokyo; www.inpex.co.jp) — have started detailed discussions on commercialization of biomethane derived from palm-oil-mill effluent (POME) in Indonesia. The consortium has been jointly studying the use of POME-based biomethane for some time. Recently, a decision was made regarding use of the PGN natural gas pipelines, which, along with the memorandum of understanding for feedstock procurement concluded with palm plantations and the expressions of interest received from customers, has led the participants to begin in-depth discussions. This phase will involve a technical assessment of supply-chain development, and biomethane production and supply, assuming that biomethane production would begin in southern Sumatra in 2025.

Although Indonesia is the world's largest producer and exporter of palm oil, POME is rich in organic material that is associated with significant emissions of methane, a gas estimated to have a greenhouse effect

(Continues on p. 7)

Upcycling waste ammonia from beef farming

A new ammonia-recovery plant has begun steady-state operation to demonstrate a patented process to upcycle the ammonia content from cattle manure into stabilized fertilizer ingredients. The Ammonia Recovery System (ARS) was developed by Bion Environmental Technologies, Inc. (Old Bethpage, N.Y.; www.bionenviro.com) as the core of the Gen-3Tech platform for sustainable beef farming. "The ARS takes advantage of the unique vapor pressure and other molecular attributes of ammonia/ammonium in order to isolate and capture the desired products of ammonia distillate and ammonium bicarbonate solution and crystals," explains Bion senior scientist, Jeremy Rowland.

"Besides the livestock manure, the only inputs to the process are heating and cooling to achieve the distillation and dewatering of the lower-weight nitrogen-containing materials produced during the digestion process, at relatively low temperatures. Repeated evaporation or distillation is employed to shed these materials of excess water, forming either a solution or a solid material that contains a combination of some organic nitrogen, ammonium and ammonium salt, including ammonium bicarbonate," says Rowland.

Furthermore, the integrated system consistently recycles the digestate byproducts to control the dewatering to either concentrate the solution or maximize it to precipitate the product. This not only includes several liquid-recycle loops to ensure all the nutrients are effectively filtered and dewatered, but also recycling the vapors and gases being continuously distilled during the full process, controlling the amount of water in the product. Rowland emphasizes that a key differentiator of ARS is Bion's ability to concentrate and stabilize ammonia using only compounds in the waste stream.

While the ARS is designed to process the effluent from any anaerobic digester system, its environmental benefits are especially significant in beef-farming applications. "In current feedlot scenarios, there is typically no water reuse, so Bion's water-recycling loops represent a significant reduction in the water footprint of beef production," says Rowland. Also, when coupled with Bion's shallow-pit barn design that quickly moves manure into the anaerobic digester on a continuous basis, environmental losses (odors and carbon and nitrogen emissions) are practically eliminated. The new ARS is located at Bion's commercial-scale demonstration facility in Fair Oaks, Ind.

Plasma-based technology for sustainable textile functionalization

A new plasma-based technology is being touted as a more sustainable method for textile finishing, including water-intensive dyeing and coating processes. The Ausora process, developed by Xefco Pty. Ltd. (Eveleigh, Australia; www.xefco.com), in partnership with the Recycling and Clean Energy Commercialization Hub (REACH) at Deakin University (Victoria, Australia; www.deakin.edu.au), uses a unique shower-plasma process to produce coatings via plasma-enhanced chemical vapor deposition (PEVCD) at atmospheric pressure. "This waterless process can produce functional effects, such as water repellency and coloration, by fixing pigments within the plasma coating," explains Tom Hussey, CEO and co-founder of Xefco. When compared with traditional wet dyeing and finishing techniques, Ausora totally eliminates water use and can reduce the use of energy and chemicals significantly (reportedly by as much as 88% and 86%, respectively).

Other precursor chemistries can be delivered besides pigments, enabling Ausora to apply a wide range of coatings and effects with strong covalent bonds to both synthetic and natural materials. The resulting coatings are extremely thin and durable, and can impart functionalities including fire retardancy, moisture wicking and odor prevention. There is also potential, says Hussey, for the technology to work well with other substrates and materials besides textiles, including in packaging, energy-storage and photovoltaic applications.

"The Ausora process can use a broad range of pigment and precursor inputs. The REACH project is centered on the use of renewable inputs with the goal of eliminating petrochemicals from textile dyeing and finishing," adds Hussey. Xefco and REACH are currently focused on refining the technology and system for commercial use. Xefco has commissioned a full-width roll-to-roll manufacturing system to demonstrate the Ausora technology within a new pilot plant at Deakin University. "Xefco has significant interest from over 15 major apparel brands and manufacturers," notes Hussey.

Machine learning approach aids 3D-printed part qualification

Metal components made with laser powder-bed fusion — an important additive manufacturing process — must be qualified for use in critical applications, but the qualification relies on expensive non-destructive evaluation (NDE) techniques. In-process monitoring offers a less expensive alternative, but existing sensing and data analysis techniques are not reliable for detecting sub-surface flaws, such as cracks and porosity.

To help address this, researchers at Oak Ridge National Laboratory (ORNL; Oak Ridge, Tenn.; www.ornl.gov), in collaboration with defense and aerospace company RTX Corp. (formerly Raytheon; Arlington, Va.; www.rtx.com), have developed a framework for quantifying the probability of detecting flaws in the component using in-process monitoring, and thus potentially reducing the expense associated with NDE and improving the confidence in a part's safety and reliability.

The framework relies on a machine-learning algorithm that is trained using information collected from sensors during the 3D-printing process, combined with data from X-ray computed tomography (XCT) of completed parts. The algorithm was trained to label flaws on the XCT scans, and was aided by human inspection. Over time, the algorithm recognizes flaws more accurately and avoids "false positives."

"We can detect flaw sizes of about 0.5 mm 90% of the time," says ORNL researcher Luke Scime. "We're the first to put a number value on the level of confidence possible for *in-situ* flaw detection," he adds.

The ORNL-developed inspection framework could help expand additive manufacturing applications. "With statistically verified quality control, additive manufacturing could become viable for mass-producing products like car parts," ORNL researcher Zackary Snow says.

25 times greater than that of CO_2.

The proposed project would recover methane gas currently released into the atmosphere from POME, refine it into biomethane, and supply it to customers in Indonesia via natural gas pipelines and other existing infrastructure.

HYBRID HEATER

Last month, Fives (Paris, France; www.fivesgroup.com) launched e-Ductflame, a patented electric/gas hybrid system intended for a wide range of heating and drying applications, and can either replace existing duct burners or be retrofitted into new installations. It has been designed to cut carbon emissions and improve the efficiency of industrial heating processes with minimum costs.

The e-Ductflame has the flexibility to operate with 100% electricity or 100% fuel gas, and has a user-friendly control interface for easy operation and maximum flexibility for fuel switching.

PFAS REMOVAL

Last month, Lanxess AG (Cologne, Germany; www.lanxess.com) intro-

(Continues on p. 8)

duced Lewatit MonoPlus TP 109, a new macroporous anion-exchange resin for the selective removal of contaminants, such as per- and polyfluoroalkyl substances (PFAS) from water. Lewatit MonoPlus TP 109 is especially suitable for the purification and remediation of water with PFAS concentrations exceeding 10 parts per billion (ppb). In addition to its high selectivity, the macroporous resin exhibits good kinetics and high fouling resistance, the company says. The uniform bead size ensures improved hydraulics, and the resin can be regenerated with chemicals, such as methanol and sodium chloride. Lewatit MonoPlus TP 109 efficiently binds not only different PFAS, but also complex anions, such as nitrate, bromate, chlorate and perchlorate. The resin can even remove chlorate from concentrated sodium hydroxide solutions.

Lanxess also offers a range of other selective resins for removing PFAS that can be combined for pre-cleaning and final polishing. One example is the heterodisperse, gel-type, strong base anion-exchange resin Lewatit TP 108 DW, which helps to remove PFAS — especially short-chain members of this substance class — even in concentration ranges of less than 10 ppb.

FOOD PACKAGING

In a pilot-scale study to find alternative raw materials for rigid plastic packages, researchers at VTT Technical Research Center of Finland (Espoo; www.vttresearch.com) have obtained unprecedented maximum limits of its highly extensible formable cellulose-based webs used for rigid packaging applications. The results enable the manufacturing of a wide range of sustainable 3D packaging solutions that were previously unattainable.

Typical commercial boards have between 3 and 6% extensibility (geometrical

(Continues on p. 9)

3D-printed reactor core improves efficiency of solar-fuel production

In recent years, engineers at ETH Zurich have developed technology to produce liquid fuels from sunlight and air. At the heart of the production process is a solar reactor that is exposed to concentrated sunlight delivered by a parabolic mirror and reaches temperatures of up to 1,500°C. Inside this reactor, which contains a porous ceramic structure made of cerium oxide, a thermochemical cycle takes place for splitting water and CO_2 (captured previously from the air) to produce synthesis gas (syngas), which can be further processed into liquid hydrocarbon fuels.

Until now, structures with isotropic porosity have been applied, but these have the drawback that they exponentially attenuate the incident solar radiation as it travels into the reactor. This results in lower inner temperatures, limiting the fuel yield of the solar reactor.

Now, researchers from the groups of professors André Studart and Aldo Steinfeld have developed a 3D-printing methodology that enables them to manufacture porous ceramic structures with complex pore geometries to transport solar radiation more efficiently into the reactor's interior. Hierarchically ordered designs with channels and pores that are open at the surface exposed to the sunlight and become narrower towards the rear of the reactor have proven to be particularly efficient. This arrangement enables the reactor to absorb the incident concentrated solar radiation over the entire volume. This in turn ensures that the whole porous structure reaches the reaction temperature of 1,500°C, boosting the fuel generation. These ceramic structures were manufactured using an extrusion-based 3D-printing process and a new type of ink with optimal characteristics developed specifically for this purpose, namely: low viscosity and a high concentration of ceria particles to maximize the amount of redox-active material.

As described in a recent issue of *Advanced Materials Interfaces*, the researchers were able to show that their new hierarchical structures can produce twice as much fuel as the uniform structures when subjected to the same concentrated solar radiation of intensity equivalent to 1,000 suns.

The technology for 3D printing the ceramic structures is patented. Synhelion SA (Lugano, Switzerland; www.synhelion.com) has acquired the license from ETH Zurich.

Scaleup of a process that makes an alternative to palm oil

A process to produce an alternative to palm oil for food applications, developed by scientists at Nanyang Technological University, Singapore (NTU Singapore; www.ntu.edu.sg), will be scaled up for commercial production through a partnership with Eves Energy Pte. Ltd. (Singapore; www.eves-energy.com). The innovation, developed by a team led by professor William Chen, director of NTU's Food Science and Technology (FST) Program, features a method that effectively produces and extracts plant-based oils from a type of common microalgae. Because the oils produced from the microalgae are edible and have superior properties, such as more polyunsaturated fatty acids, as those found in palm oil, the newly discovered method would serve as a healthier and "greener" alternative to palm oil.

To produce the oils, pyruvic acid is added to a solution with the algae *Chromochloris zofingiensis* and exposed to ultraviolet light to stimulate photosynthesis. After 14 d, the microalgae are washed, dried and then treated with methanol to break down the bonds between the oils and the algae protein, so that the oils can be extracted. After the oil has been harvested, the rest of the plant, which is edible, is converted into algae cake, a nutrient-rich food product that can be converted into supplements.

In 2024, Eves Energy will set up a facility in Indonesia with 400,000 tanks that could produce 1.2 million metric tons (m.t.) of microalgae oil and 1.2 m.t. of algae cake within two years. In addition to being an alternative to palm oil, the microalgae oil could also be a sustainable source of renewable energy.

Due to its low cost and high yield, palm oil is said to be the world's most popular vegetable oil. It is found in about half of all consumer products. However, widespread deforestation in several countries and the destruction of habitat of endangered native wildlife have been blamed on the rapid expansion of oil-palm plantations. Cultivating microalgae for its oil is a more sustainable and environmentally responsible alternative to palm-oil production. The rapid growth cycle of algae facilitates quicker and more efficient oil production compared to the years required for palm trees to mature.

Synthetic chemistry advance allows swaps of aromatic C atoms with N

Substituting nitrogen atoms for aromatic carbon atoms at specific locations within the molecular skeleton of a possible therapeutic agent can have significant effects on molecular properties critical for biological activity, such as hydrogen bonding, polarity, metabolic stability, target specificity and solubility. The ability of medicinal chemists to effect C-to-N "transmutations" of aromatic and heteroaromatic skeletons has been extremely limited, making studies of structure-activity relationships difficult and time-consuming.

Now, two new synthetic chemistry pathways developed by chemists in the laboratory of Mark Levin at the University of Chicago (www.uchicago.edu) allow targeted removal of carbon atoms within an aromatic ring and replacement with a nitrogen atom. The "one-pot" techniques could dramatically streamline investigations of potential drug molecules.

In the first technique, quinolines (benzene and pyridine ring fused at adjacent carbons) were converted to the corresponding quinazolines (benzene-pyrimidine) by activating the to-be-substituted carbon as a labile leaving group. To do this, ozone is used to open the aromatic ring containing the N atom. Once open, the ring has two electrophilic positions that accept an incoming nucleophilic nitrogen (in the form of ammonium carbonate) and re-close the ring with the new N atom taking the place of the carbon. The carbon is pushed out as part of a carbonyl leaving group.

The second technique substitutes a N atom for a C atom in an aromatic ring without any existing N atoms. The scientists irradiated an arene-derived azide to form an azepine (seven-member heterocyclic ring with one N atom). The team oxidized the azepine ring using carefully selected oxidant species that allowed the elimination of the targeted carbon and incorporation of the N atom into the ring at the same location.

The team envisions a host of synthetic applications for the site-specific replacement of C atoms with N. The two approaches were recently published in the journals *Science* and *Nature*, respectively. ■

mean) and best commercial formable boards have 10–18% extensibility. By utilizing foam-forming technology, VTT has now obtained up to 30% extensibility. This enables brand owners to use rigid, cardboard-like packaging to serve consumers looking to buy more sustainable products.

VTT, together with gruppo x di x gruppo s.r.l. (Venezia, Italy; www.gruppox.it) and Lappeenranta-Lahti University of Technology (LUT; Finland; www.lut.fi), were able to incorporate the product into existing product packaging lines with no changes in the process. ❐

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Plant Watch

Petrobras announces biorefining breakthrough at Riograndense refinery

November 9, 2023 — Petróleo Brasileiro S.A. (Petrobras; Rio de Janeiro, Brazil; www.petrobras.com.br) has successfully processed 100% soybean oil in a fluid catalytic cracking (FCC) unit at its Riograndense petroleum refinery (RPR). With the success of this test, RPR is prepared to initiate the production of renewable feedstocks and fuels, including renewable marine fuels, renewable propylene and bio-aromatic hydrocarbons (benzene, toluene and xylenes), which are needed to produce synthetic rubber, nylon and polyvinyl chloride (PVC).

Thyssenkrupp Uhde and Proman to collaborate on ammonia plant in Mexico

November 8, 2023 — Thyssenkrupp Uhde GmbH (Dortmund, Germany; www.thyssenkrupp-uhde.com) has been engaged by Proman (Wollerau, Switzerland; www.proman.org) to realize a new ammonia plant in Topolobampo, Sinaloa, Mexico, which will have a production capacity of 2,200 metric tons per day (m.t./d). Thyssenkrupp Uhde will provide engineering and procurement services, in addition to ammonia technology license and proprietary equipment.

Air Products to build 'blue' hydrogen plant to supply ExxonMobil site in Rotterdam

November 7, 2023 — Air Products (Lehigh Valley, Pa.; www.airproducts.com) will build, own and operate a new carbon capture and carbon dioxide treatment facility at its existing hydrogen production plant in Rotterdam, the Netherlands. The facility is expected to be onstream in 2026, and the resulting "blue" hydrogen will serve ExxonMobil's Rotterdam petroleum refinery and additional users via Air Products' hydrogen pipeline network system.

DuPont starts up new elastomer plant in Delaware

November 6, 2023 — DuPont (Wilmington, Del.; www.dupont.com) has opened a new manufacturing site and cleanroom facility for Kalrez-branded perfluoroelastomer parts in Newark, Del. to meet growing global demand from the semiconductor, chemicals and other industrial sectors.

Versalis begins construction of chemical recycling plant in Italy

November 1, 2023 — Versalis S.p.A. (San Donato Milanese, Italy; versalis.eni.com) started construction on a demonstration plant in Mantua to develop its proprietary technology for chemical recycling of mixed plastic waste. The plant will have capacity to handle 6,000 m.t./yr of secondary raw material, and is scheduled to start up by the end of 2024.

Dow and Evonik start up pilot plant for new propylene glycol technology

November 1, 2023 — Dow (Midland, Mich.; www.dow.com) and Evonik Industries AG (Essen, Germany; www.evonik.com) have started up a pilot plant at Evonik's site in Hanau, Germany that converts hydrogen peroxide into propylene glycol (PG). In contrast to the traditional PG process, where propylene is used to make propylene oxide, which is converted to PG through hydrolysis, this process uses a new catalyst to generate PG directly from propylene and hydrogen peroxide.

Nouryon begins production at microspheres plant in Wisconsin

October 31, 2023 — Nouryon (Amsterdam, the Netherlands; www.nouryon.com) has started production at its new expandable microspheres plant in Green Bay, Wis., which will supply specialty additives to the packaging, construction, mining and automotive industries. It complements the company's existing full-scale plant in Sundsvall, Sweden, and product-expansion facilities in China and Brazil.

Asahi Kasei to expand global capacity for LIB separator coating

October 31, 2023 — Asahi Kasei Corp. (Tokyo, Japan; www.asahikasei.com) will invest in additional equipment for coating lithium-ion battery (LIB) separators. New coating lines will be installed at existing facilities in the U.S., Japan and South Korea, with startup scheduled in 2026. The investment for the project will be approximately ¥40 billion ($264 million).

BASF begins production at superabsorbents center in Belgium

October 26, 2023 — BASF SE (Ludwigshafen, Germany; www.basf.com) started production at its new superabsorbents center at its *Verbund* site in Antwerp, Belgium. The €25-million investment will contribute to the BASF hygiene business as part of its acrylics value chain.

Lubrizol and Grasim break ground for CPVC resin plan in India

October 25, 2023 — The Lubrizol Corp. (Cleveland, Ohio; www.lubrizol.com) and Grasim Industries Ltd. (Mumbai, India; www.grasim.com) have broken ground on the first phase of a 100,000-m.t./yr chlorinated PVC (CPVC) resin plant in Vilayat, Gujarat, India. This facility will be the largest single-site capacity for CPVC resin production globally.

Covestro launches mechanical-recycling polycarbonate compounding line in China

October 24, 2023 — Covestro AG (Leverkusen, Germany; www.covestro.com) has commenced operations at its first dedicated mechanical-

recycling compounding line for polycarbonates at its integrated site in Shanghai, China. This line is set to produce over 25,000 m.t./yr of premium-quality polycarbonates and blends containing mechanically recycled materials.

Mergers & Acquisitions

Yara to divest Ivory Coast fertilizer business

November 10, 2023 — Yara International ASA (Oslo, Norway; www.yara.com) announced the divestment of its fertilizer import and distribution subsidiary in Ivory Coast. The divestment transaction is anticipated to be finalized by the end of April 2024 and will enable Yara to allocate resources and investments toward other selected countries in Africa.

Eni and Saipem sign agreement to develop new biorefineries

November 7, 2023 — Eni S.p.A. (Rome, Italy; www.eni.com) and Saipem S.p.A. (San Donato Milanese, Italy; www.saipem.com) have signed an agreement for the development of biorefining projects, with focus on the production of sustainable aviation fuel (SAF) and diesel products based on hydrotreated vegetable oil (HVO). This agreement will contribute to Eni's plans to expand its biorefining capacity from the current 1.65 million m.t./yr to over 5 million m.t./yr by 2030.

Henkel acquires MRO specialist Critica Infrastructure

November 3, 2023 — Henkel AG & Co. KgaA (Düsseldorf, Germany; www.henkel.com) has acquired the U.S.-based firm Critica Infrastructure, a specialized supplier of maintenance, repair and overhaul (MRO) composite products for critical infrastructure, including oil-and-gas transmission and municipal water-supply systems. Critica is active in many countries and is expected to reach sales of around $110 million in 2023.

Clariant to acquire cosmetics business from IFF

October 31, 2023 — Clariant AG (Muttenz, Switzerland; www.clariant.com) has agreed to acquire Lucas Meyer Cosmetics, a leading provider of ingredients for the cosmetics and personal-care industry, from International Flavors & Fragrances (IFF; New York, N.Y.; www.iff.com) for a total cash consideration of $810 million.

Sandvik acquires tungsten manufacturer in New York

October 27, 2023 — Sandvik AB (Stockholm, Sweden; www.sandvik.com) will acquire Buffalo Tungsten, Inc. (BTI), a New York-based manufacturer of tungsten metal powder and tungsten carbide powder. BTI will be part of the Sandvik Machining Solutions (SMS) business segment. This will complement Sandvik's existing production site for similar products in St. Martin, Austria.

Lummus acquires Air Liquide acrylic acid and acrylates technologies

October 26, 2023 — Lummus Technology (Houston; www.lummustechnology.com) will acquire rights to process technologies for ester-grade acrylic acid and light and heavy acrylates from Air Liquide Engineering & Construction. The addition expands Lummus' portfolio for propylene production and derivative products. ■

Mary Page Bailey

Membranes and Filters Handle Separation Issues

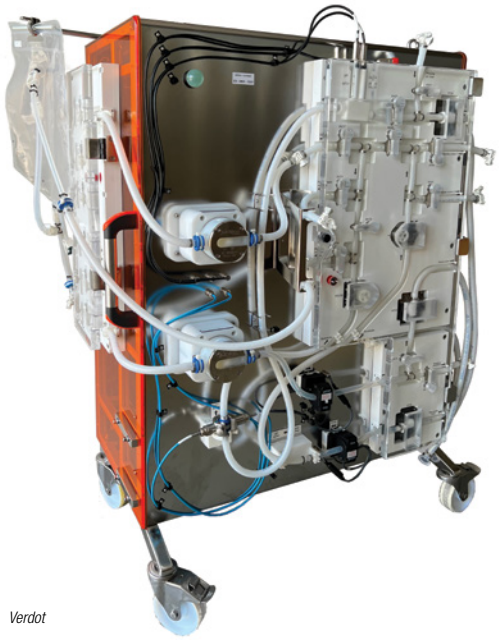
Tailored separation systems address energy consumption and fouling while supporting sustainability

IN BRIEF

Recently there has been a demand for separation technologies that are better suited to specific applications and a more sustainable world, so providers of filters and membranes have begun using innovative techniques to create enhanced technologies that not only address challenges, such as high energy consumption, fouling and sustainability, but may also allow tailor-made approaches in traditional and new separation processes.

New techniques drive improvements

As separations become more important in the chemical process industries (CPI) due to sustainability initiatives, such as energy efficiency, zero-liquid discharge and decarbonization, as well as a desire to recover valuable materials from waste streams, developers of filters and membranes are employing new research and development techniques in an effort to improve their offerings by making them more efficient, more productive and easier to use, while also overcoming known challenges and targeting specific applications that rely heavily on separations.



Verdot

FIGURE 1. Certain biopharmaceutical application challenges, including shear stress during processing and product recovery post-processing, can be addressed with Verdot's FlexiPro TFF system

"Membranes, especially, are viewed as a black box technology and that can make operators a little bit hesitant to use them, so the more we can do to improve them and prove that they are going to be very stable and operate with high reliability, the more operators will start feeling comfortable with them," says Christine Parrish, director of technology, with Compact Membrane Systems (CMS; Newport, Del.; www.compactmembrane.com).

To that end, companies like CMS are using a variety of techniques to build better, more effective systems. "There's been a lot of modeling to provide us with an understanding of how things work," explains Parrish. "For example, we have developed a model that allows us to evaluate up to 27 different configurations for each separation and determine which one spits out either the lowest cost system or the lowest energy use in a system. This is helpful because different users have different needs and having options allows us to give each customer a tailored solution without tailor-making a product for each one of them."

Additionally, advanced analytical and imaging techniques are being employed by technology developers so that they may better characterize membranes and membrane surfaces, allowing them to design more effective and reliable membranes, says Nick Adams, director of research, membranes, with Veolia Water Technologies & Solutions (Trevose, Pa.; www.watertechnologies.com). "Using these techniques to improve processing conditions and understand the reaction kinetics allows us to better tailor membranes for improved flux performance and tailor rejection characteristics," he explains.

Fortunately, the use of these techniques is resulting in new separation technologies that outperform traditional membranes and fil-

FIGURE 2. Eaton's BECO Carbon ACF 03 grade was developed in response to the growing demand for user-friendly activated carbon sheets tested for endotoxins for pharmaceutical and biopharmaceutical applications, fine chemicals and other industries

ters, as well as the systems that support them. "For one thing, scientists are learning to think about field conditions earlier so that the technologies they develop are tailored for the field conditions rather than retrofitted to the field once they are handed off to industry. And when we start thinking about the system design, sometimes we find that the answer is not always to make the membrane itself inherently more selective or more permeable, but the answer is really to change how we design it in the field," says Parrish.

"For example, perhaps instead of using a one-stage membrane, maybe we break it into two stages and that's actually the most efficient separation," she continues. "This type of thinking and development allows us to harness the power of the membrane into something that provides both the high purity and high recovery that a particular separation process needs."

Other areas of improvement include composite solutions, says Parrish. "In some applications we have reached the limit of what you can do with a single membrane constituent. But using composite solutions, such as where you take a hollow fiber or flat-sheet membrane and coat an even more selective layer on top, may provide the next horizon of membranes.

"Further, mixed matrix membranes and developments that incorporate more chemistry to boost the membranes and make them more powerful, rather than just relying on the mechanical properties of the membranes and size exclusion, are the breakthroughs that will allow membranes to be introduced into a lot of very valuable separations," continues Parrish.

Veolia's Adams adds: "Traditionally there is a trade-off between productivity and rejection performance, so some of the developments we are working on try to break that curve so we can not only get a highly productive membrane, but also have the ability to tune the rejection characteristics and not be stuck on this curve where we can have only one or the other. Based on this thought process, we are working on the use of new materials and different coating techniques."

Other innovations are targeted at specific performance issues. "Currently we are working on research to develop a membrane with high resilience to biofouling and the ability to work in higher fluxes," says Jacky Ben Yaish, vice president of engineering with IDE Technologies (Kadima, Israel; www.ide-tech.com). "Polymer membranes are sensitive to chlorine and other oxidizers and have a limit to the flux of permeate that can pass through them. New membrane technology speaks of graphene membrane, which will replace polyamide membrane working in a very high-flux graphene membrane. This will be supported by a rigid ceramic body and not a polysulfide layer and a polyester base, enabling a membrane with a very high resilience."

Tailored separation approaches

Because the focus of current and future developments has been on tailoring separation technologies, many of the latest innovations target solutions for specific issues or applications.

For example, Verdot (Riom, France; www.verdot-biotechnologies.com), which focuses on downstream purification solutions for the biopharmaceutical and food-processing sectors, recently developed a liquid-handling system that enables precision tuning of the filtration process, says Sébastien Lefebvre, vice president of research & development, with Verdot. "Certain biopharma application challenges needed to be addressed, including shear stress during processing and product recovery post-processing. Our FlexiPro TFF system [Figure 1], which is compatible with filter formats including membranes, cassettes or hollow fibers, is specifically designed to minimize shear stress and allow high product recovery in the post-processing stages.

"It addresses this specific market need with interchangeable pump heads and tubing to address process-specific volumes and flowrates within the same instrument, thus reducing the footprint and time needed to validate multiple systems. The single-use system is GMP-compliant and scalable from process development to small scale through commercial manufacturing while also supporting today's sustainability practices by addressing the specific challenge of water reduction and chemical consumption during cleaning," Lefebvre says.

Meanwhile, in pharmaceutical and biopharmaceutical applications where filtration is used to improve the quality of the end product or protect plant components, the filtration systems must meet the highest demands in terms of efficiency, purity and cleanability. And, because chemical active pharmaceutical ingredients (APIs) production is carried out using a variety of solvents under a range of application conditions, including pH levels, pressure and temperature, filter components must be resistant to these conditions and obtain reliable results, says Joerg Thiemann, product manager, filter media, with Eaton Filtration (Langenlonsheim, Germany; www.eaton.com). "With our new BECO Carbon ACF 03 grade, we are responding to the growing demand for user-friendly activated carbon sheets [Figure 2] tested for endotoxins for pharmaceutical and biopharmaceutical applications, fine chemicals and other industries. API manufacturing processes, in particular, demand the strong capabilities of activated carbon depth filter sheets for decolorization and adsorptive separation of undesired byproducts. In these processes, users benefit from the fact that these activated carbon depth filter sheets must meet USP Class VI testing requirements and a Validation Guide," Thiemann says.

Water treatment is also reaping

Veolia

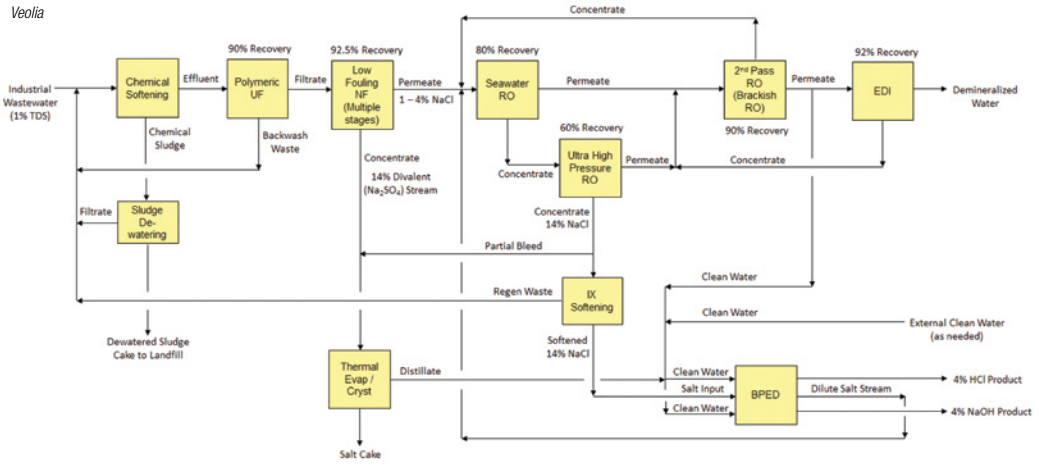


FIGURE 3. Veolia's brine concentration flowsheets use several different membranes in combination, allowing users to achieve maximum water recovery in a more economic way that limits the use of thermal processes

the rewards of the latest innovations that strive to overcome known challenges. "Unlike thermal desalination plants, reverse-osmosis (RO) membrane plants are susceptible to the raw water quality and, because of that, every desalination plant based on a polymer membrane has a pretreatment upstream, which can be sand filters, ultrafiltration or operation units for water containing high quantities of debris, TSS [total suspended solids] and total suspension," explains IDE's Yaish. "Furthermore, a desalination plant based on membrane technology is subject to biofouling and the way to treat biofouling is to remove organics before the membranes. Additionally, desalination plants based on RO membranes consume energy due to the high osmotic pressure."

To tackle these challenges, IDE introduced its Pulse Flow RO (PFRO) technology. Conventional RO doses anti-scalant to prevent scaling in high recovery RO processes and chloramine or biocides to prevent biofouling. Stability in concentration, flow and gage and osmotic pressure are the best conditions for the formation of scaling, fouling and biofouling. Stability of the membrane surface geometry also contributes to all forms of fouling. "IDE's PFRO technology is completely contrary to conventional RO operation. The flow is not stable and the osmotic gage and pressure change frequently and rapidly. The membrane geometry breathes according to change in feed and permeate pressure," explains Yaish. "This method has six times the ability of the standard RO process to remove concentrated solute ions or fouling particles. In between brine discharge pulses, the RO membrane operates in dead-end mode, with 100% recovery."

Veolia is also working on solutions for the water treatment industry that focus on edging users closer to a more affordable zero-liquid-discharge solutions as more cost-effective sustainability becomes a growing issue. "Our brine concentration flowsheets [Figure 3] use several different membranes in combination, allowing users to achieve maximum water recovery in a more economic way that limits the use of thermal processes," says Adams. "Those flowsheets also open the door for being able to recover resources, as opposed to ending up with a highly concentrated brine stream that needs disposal. To do this, we use flowsheet technology to separate valuable ions or recover acids and bases so they don't end up with a highly concentrated waste stream at the end."

Sustainability & decarbonization

As sustainability and decarbonization continue to become priorities, membrane developers are also working to provide solutions that support these efforts. Evonik Industries AG (Essen, Germany; www.evonik.com), for example, is providing technologies for membrane-based biogas separation. Biogas is produced by the fermentation of biomass, an organic substance from waste, such as liquid manure, sewage sludge or renewable raw materials, but traditional biogas-upgrading processes, such as pressurized water scrubbing, pressure-swing adsorption or amine scrubbing, are energy intensive and produce waste and wastewater. In response, Evonik developed Sepuran Green hollow fiber membranes (Figure 4), which easily and efficiently separate raw biogas, which consists of the energy carrier biomethane and renewable carbon dioxide, into high-purity biomethane and bio-CO_2. "The climate friendly energy source can consequently be used to generate electricity and heat or used as fuel. bio-CO_2, on the other hand, can be liquefied onsite and used as a renewable raw material for various applications," says Goetz Baumgarten, head of membranes innovation growth field at Evonik. "These membranes are made of a high-performance polymer specially developed to be highly resistant to pressure and temperature. They require very little energy and do not need any auxiliary materials or chemicals. No waste or wastewater is produced that would otherwise have to be treated and require disposal."

And, CMS is focused on how to use membranes to enable the decarbonization revolution, says Parrish. "We have recently developed a facilitated mechanism platform, called Optiperm FTM [facilitated transport

Evonik

FIGURE 4. Evonik's Sepuran Green hollow-fiber membranes easily and efficiently separate raw biogas, which consists of the energy carrier biomethane and renewable carbon dioxide, into high-purity biomethane and bio-CO_2

FIGURE 5. A commercial demonstration of CMS's Optiperm FTM system and membranes at a Braskem manufacturing site demonstrates the commercial-sized membrane modules in a multi-stage unit for olefin recovery from a polypropylene reactor purge

membrane] that allows users to do really important separations without relying on pressure as the driving force, so it gives the energy boost that everyone is looking for. We are focused on addressing olefin-paraffin and carbon-capture separations with this new technology.

"Distillation columns are the incumbent technology in these separations, but our membranes can do what a distillation column does in membrane form and that translates to typically 2 to 8% capacity increase and 30% or greater energy efficiency with a 70% reduction in greenhouse gas compared to running the same molecules through a column," says Parrish. "We are running a commercial demonstration of the full system and membranes now at a Braskem manufacturing site [Figure 5] and the membranes are showing stability even in an environment with harsh conditions and field contaminants. The FTM mechanism is surrounded by very durable chemistry and that allows it to work practically in the field."

The pilot is intended to demonstrate the commercial-sized membrane modules in a multi-stage unit for olefin recovery from a polypropylene reactor purge. The project is expected to address the critical milestones of simultaneously producing high-purity (>95%) paraffin and (>90%) olefin-rich streams with a multistage membrane design. The demonstration-unit design features membrane areas balanced between two stages and a full control system to meet stream purity specifications.

At the same time, CMS is building a pilot unit with a steel producer on the use of the FTM technology in point-source carbon capture. "We believe it can have a gigaton impact on CO_2 emissions in heavy industry such as steel, cement and chemicals," she says. "When fluegas is emitted from these industries, it is in atmospheric conditions and it's hot and wet and difficult to deal with. The beauty of the FTM membranes is that they like warm conditions and prefer humidified environments, so they work better when water is present and operate well at low pressure. This means they are a match made in heaven between the operating conditions of the membranes and the fluegas as it leaves the stack. And because this is a continuous process operation, it's easy to operate because users don't have to run batches or regenerate membranes. We see that we can make a big impact on the world's carbon footprint with this technology." ■

Joy LePree

Level Measurement & Control

Krohne Messtechnik

Berthold Technologies

Endress+Hauser

Ametek Level Measurement Solutions (LMS)

New magnetic level indicator completes series

A wide range of options have been added to the BM26 Series of magnetic level indicators (MLI) since it was first introduced in 1955. With the recent introduction of the new BM26A-8000, the company completes the series. The BM26A-8000 for redundant level measurement in liquid applications is available in two versions. The BM26A-8000-TWIN (photo) consists of a double measuring chamber with one chamber featuring a flapper indication, and the other one acting as a bypass chamber equipped with a time domain reflectometry (TDR) guided radar, frequency modulated continuous wave (FMCW) radar or displacer level transmitter. The BM26A-8000-BI version features a unique measuring chamber with two compartments, one for the Optiflex 7200 TDR transmitter probe and one for the float moving next to it. — *Krohne Messtechnik GmbH, Duisburg, Germany*

www.krohne.com

Monitor two different levels simultaneously with this unit

Compared to the classic radiometric level measurement, the LB 476 Level+ system (photo) enables the storage of two calibration curves, as well as simultaneously monitoring two product levels based on those calibration curves. Moreover, by using the compensation functions, level-measurement falsifications due to, for example, gas-density fluctuations or due to product buildups, are no longer a concern. Dual-level measurement can be especially useful for level measurements of products in processes with two significantly different process stages (for example, normal and outage stage in the delayed coking process). The LB 476 Level+ system can be used with both LB 4700 DuoSeries detectors (two wires) or LB 480 SENSseries detectors (316L housing as option and own current output). — *Berthold Technologies GmbH & Co. KG, Bad Wildbad, Germany*

www.berthold.com/level-plus

Optimizing supply chains with wireless level measurement

The Micropilot FWR30 IIoT radar sensor (photo) measures fill levels in mobile tanks, containers and silos. The values are sent to the cloud so that they are available at any time and from anywhere. Close cooperation with users of the innovative sensor has led to further expansion of its fields of application since its market introduction three years ago. As well as liquids, the instrument can now measure bulk solids and even perform measurements in metal containers. The battery-operated sensor requires no infrastructure in the form of power supplies or cables. The only prerequisite is adequate mobile network coverage at the container site. The FWR30 can be mounted on the container in just a few steps. After scanning a QR code, the system is immediately ready to operate and integrates automatically into this company's Netilion IIoT ecosystem. Measurement values are sent via the cloud to mobile or stationary end-user devices at configurable intervals. — *Endress+Hauser AG, Reinach, Switzerland*

www.endress.com

This displacer liquid level transmitter has many features

The Magnetrol E4 Modulevel (photo) is a state-of-the-art 24-V d.c., loop-powered, displacer liquid level transmitter. It offers the capability to output total level, interface level or specific gravity. By utilizing the LVDT/Range Spring technology, this transmitter is said to deliver superior measurement stability and performance compared to traditional torque-tube displacer transmitters. This enhanced E4 transmitter aligns with the latest Magnetrol family of level transmitters, providing intuitive operation and ease-of-use through faster commissioning, maintenance and troubleshooting. Some of the key features include: a graphic LCD featuring an easy-to-navigate menu structure; a graphical DTM with increased diagnostics (compatible with PACTware); NAMUR NE 107 diagnostic coverage; HART digital output (Version 7); and it can be retrofitted onto existing displacer

assemblies without interrupting the process. — *Ametek Level Measurement Solutions (LMS), Aurora, Ill.*
www.ametek-measurement.com

A new radar sensor for level measurement

Dulcolevel (photo) is a new radar level sensor that provides continuous information on tank liquid levels. This ensures tanks can be refilled on time without any process interruption and makes chemical-inventory management straightforward. In parallel to this, a specific Inventory Management module has been added to the Dulconnex cloud platform. Thanks to both innovations, operators of water and wastewater technology, as well as chemical distributors and service providers in the disinfection sector, can now obtain a complete digital fluid-management system from a single source. All the products required, from the sensor and pump to the measuring and control technology, are perfectly matched and networked. In practice, this allows any number of sites with pump installations to be monitored, operated and supplied remotely in real time via the cloud platform. Liquid levels, pump outputs and consumption are automatically available, along with complete reports. Smartphone alerts provide early warning of low levels or potential system downtimes. — *ProMinent GmbH, Heidelberg, Germany*
www.prominent.com

Radar level transmitters that are Bluetooth enabled

The Rosemount 3408 level transmitter (photo) is a non-contacting radar device designed to optimize ease-of-use, leading to increased safety and enhanced plant performance. While the benefits of radar level measurement are widely acknowledged, the company says radars are still sometimes perceived as being complex to commission, operate and maintain. Addressing this concern, the device provides a range of functions that reduce complexity throughout its lifecycle, including a highly intuitive interface, Bluetooth wireless technology remote capabilities, predictive alerts, in-situ verification, data historian and an upgradeable design. The user interface provides clear pictorial instructions, allowing operators to be easily guided through installation, commissioning, proof-testing, operation and maintenance. This increased ease-of-use gives process and manufacturing organizations the confidence to replace time-consuming manual procedures, thereby helping to increase safety and maximize productivity. — *Emerson, St. Louis, Mo.*
www.emerson.com

Level control using load cells

Compared to other technologies, such as ultrasonic and free-radiating radar, load cells offer several key advantages for measuring fill level in containers, according to this company. Firstly, load cells provide very accurate weight and level measurements regardless of the material. Secondly, they are very robust, which leads to a long service life. Another advantage is that the load cells are mounted below the container, which avoids perforation of the container and thus significantly improves hygiene. In order to be able to use the weight values efficiently in the production processes, the signals from the analog load cells must be determined and passed on to the production control system. These tasks are performed by weighing transmitters. Using a standard web browser, the Link E weighing transmitter (photo) can be easily configured, without having to install additional software. Link E handles nine different interfaces and fieldbuses, including Profibus, ProfiNet or Ethernet/IP. — *Minebea Intec GmbH, Hamburg, Germany*
www.minebea-intec.com

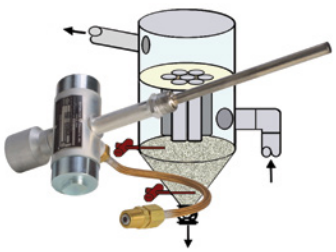
Field-proven level switch for baghouse dust collection

The DJ Level Switch (photo) is designed for high- or low-point level detection of bulk solids. Suitable for use in baghouses, cyclone separators, above airlocks or collection bins for challenging applications found in dust collection systems. The rugged design and vibrating probe prevents buildup and ensures reliable level measurement. Consistent results have been achieved on chemical dust or powders, minerals (including fumed silica), acid powders, potash, potassium and other bulk materials. The switches require no adjustments, and have no moving parts or gaskets or seals to deteriorate, making them virtually wear-free, the company says. Specialized units are available for temperatures in excess of 500°F.

ProMinent

Emerson

Minebea Intec



Automation Products

BinMaster

VEGA Grieshaber

Pepperl+Fuchs

Rechner Electronics Ind.

They are approved for Class III services, as well as for Class I, Groups C & D; Class II, Groups E, F & G; Class III. — *Automation Products Inc., Dynatrol Division, Houston*
www.dynatrolusa.com

A new rotary paddle level switch

The new BMRX-200 rotary level paddle switch (photo) includes a DPDT (double pole double throw) relay and fail-safe high and fail-safe low. The new red enclosure can be rotated once it is installed. This feature makes it easy to ensure conduit entries are always pointed toward the ground, mitigating the risk of moisture damaging internal components. New guides ensure wires do not get stuck as users push them through conduit entries. A rotary paddle switch is used for point level detection in powders, pellets and granular materials with a bulk density of 2 lb/ft^3 to over 100 pounds per cubic foot. They can be installed in bins and silos for overfill prevention and to eliminate material outages that could interrupt a process. Other uses include plugged chute detection and to conveyor overloading prevention. Couplers and paddles sold separately. — *BinMaster, Lincoln, Neb.*
www.binmaster.com

This radar sensor now has IO-Link communication

IO-Link is of particular importance as a communication protocol for the complex measuring tasks in factory automation. Fast, simple and cost-effective, Vegapuls 42 sensors meet the high demands of the industry and completes the IO-Link family of this company, which now offers a complete portfolio for level, switching and pressure. With its versatile hygienic adapters, Vegapuls 42 is particularly suitable for processes with strict hygiene standards. The radar sensor is equipped with all the necessary state-of-the-art functions. It enables communication with IO-Link, which means bidirectional data transmission with extensive diagnostics and parameterization. Vegapuls 42 is designed for a measuring level up to a distance of up to 15 m and can be used in temperatures up to 150°C. The sensor configuration is suitable for cyclical production processes, dosing processes and downstream processes, such as conveyance and filling systems. — *VEGA Grieshaber KG, Schiltach, Germany*
www.vega.com

Vibration limit switches for hazardous areas

Vibration limit switches reliably detect the fill level of liquids at all times. With Vibracon LVL-M3 and -M4 (photo), this company offers two new series of vibration limit switches that can be used worldwide in hazardous areas due to ATEX and IECEx approvals. The LVL-M3 version is suitable for universal use in all pumpable liquids. The vibration limit switch can withstand process temperatures of –40 to 150°C and process pressures of up to 40 bars. The LVL-M4 version is suitable for safety applications up to SIL 3. The sensor is resistant to process temperatures of –50 to 150°C and process pressures up to 100 bars. The LVL-M4 version has a Bluetooth interface that can be used to connect the device to the company's Level App. This mobile application enables status and fault indication to proof testing. — *Pepperl+Fuchs SE, Mannheim, Germany*
www.pepperl-fuchs.com

Capacitive level sensor with EHEDG certification

Sensor KA1244 (photo) has a hygienic-designed housing and is certified by the European Hygienic Engineering and Design Group (EHEDG), with certification type EL Class I. The polyether ether ketone (PEEK) surface has the high-quality Ra 0.4 µm for smoothness and the PEEK conforms to EC 1935/2004 for traceability of the materials. The beveled-edge body design prevents the possibility of contamination around the weld mount or varivent adaptor. This allows the sensor to stay in place while the system is cleaned for a product changeover. A clean-in-place Tri-clamp mounting is also an option. The PEEK housing is FDA 21 CFR 177.2415 compliant for use in food and pharmaceutical applications. The sensor is pressure rated for 10 bars. Users can select either horizontal or vertical mounting. Applications include high- and low-level control of cereals, water, juice, wine, oil, shampoo, pharmaceutical chemicals and many other products. — *Rechner Electronics Ind. Inc., Sanborn, N.Y.*
www.rechner-sensors.com ■

Gerald Ondrey

New Products

Hearing protection for demanding environments

NC-520XP hearing-protection headsets (photo) are designed for use in demanding environments. They incorporate Dual Bluetooth, which enables the connection of two Bluetooth devices simultaneously (such as a smartphone or radio), enabling hands-free communication. This also allows users to listen to radio transmissions and still be reachable. The noise-canceling Push-to-Talk (PTT) boom microphone ensures clear speech even in the loudest of environments. The headsets also feature a user-friendly answer button and rotary switch for convenient control of ambient sound volume and incoming communication. The headset has a rechargeable power unit designed for maximum durability. — *Savox Communications Oy, Espoo, Finland*
www.savox.com

Savox Communications

Checking tablets, even under containment conditions

The new Checkmaster CM-X (photo) tests tablets randomly, and in compliance with OEB4 containment conditions, in interaction with this company's F10i, F20i and F30i tablet presses from the new i Series. The Checkmaster CM-X tests the produced tablets for weight, diameter, thickness and strength/hardness. The equipment thus supplements the range of tablet test devices already available. With the i Series' ergonomic human machine interface (HMI), the Checkmaster CM-X is easy to operate while minimizing the risk of errors, because manual data entry is no longer required. — *Fette Compacting, Schwarzenbek, Germany*
www.fette-compacting.de

Fette Compacting

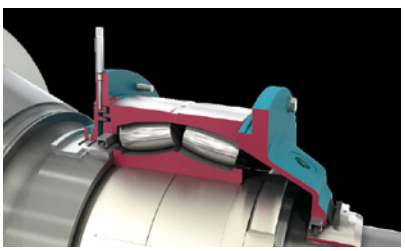
Check packaging integrity with this leak detector

The new SpeedAir 3050 leak tester (photo) is an all-in-one system for nonporous pharmaceutical containers. SpeedAir offers container-closure integrity testing (CCIT) for a wide range of products, including flexible or rigid, liquid or solid packaging. Typically requiring only 30–45 s, this mass extraction instrument quickly and efficiently delivers results, ensuring the integrity of pharmaceutical containers. Unlike alternative methods that focus on specific areas or access points, the SpeedAir provides a comprehensive global non-destructive testing (NDT) approach that adheres to ASTM Standard F3287-17. — *Pfeiffer Vacuum GmbH, Asslar, Germany*
www.pfeiffer-vacuum.com

Pfeiffer Vacuum

Secure bearing lubrication in fiber-processing equipment

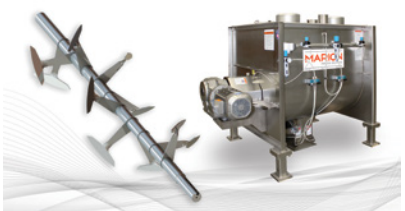
As various rotating machinery throughout fiber-processing operations experience extremely harsh and demanding environments, it is often difficult to manually retrieve oil samples. Maintaining an adequate surveillance of lubrication properties against harmful effects can prove very challenging. This company's oil-monitoring system (photo) provides constant, remote condition-monitoring of lubrication-oil systems. Damages in rotating equipment bearings are often related to insufficient bearing lubrication. Typical failure modes, such as bearing vibration and elevated temperature, are normally only observed when the failure has already progressed. With this new oil-monitoring technology, upcoming failures can be predicted through changes in lubrication-oil quality. The device enables corrective actions before the actual failure arises, reducing unplanned shutdowns and the need for subsequent repairs. — *Valmet Oyj, Espoo, Finland*
www.valmet.com



Valmet

New paddle agitator offers fast product validation

With new manufacturing improvements to its standard plated paddle agitator (photo), this company can speed up lead times on its 30-in. dia. and smaller-sized horizontal mixers. The new plated paddle agitators are manufactured with the paddle and arm sections cut from a single piece of stainless steel, reducing welding requirements and offering operators low-maintenance cleanability. Due to the integrated placement hole design, additional arms are attached, which means that the length of the paddles are shortened to offer improved mixing efficiency. — *Marion, a part of Advanced Material Processing, Marion, Iowa*
www.marionsolutions.com



Marion, a part of Advanced Material Processing

Brabender

GEA Group

Charles Ross & Son

View Tech Borescopes

Exair

Efficient density determination for rubber compounds

Within rubber production facilities, density is an important process parameter that correlates with the degree of cross-linking or the hardness of the elastomer used. The determination of the density is therefore of great importance for the development of recipes and quality control. The ElaTest measuring system (photo) is designed for density determination of non-vulcanized (uncured) rubber and rubber compounds. With its rapid measuring method, integrated scale and robust design, the ElaTest system is suitable for challenging applications, such as tire manufacturing. — *Brabender GmbH & Co. KG, Duisburg, Germany*
www.brabender.com

This spray dryer has a cyclone separator

The Mobile Minor MM 100 spray dryer (photo) is equipped with the Cyclone CEE mechanical powder separator. This cyclone helps operators overcome challenges in spray drying, such as smearing due to powder settling in the cyclone, as well as abrasion and the resulting costly production downtime. The Mobile Minor MM 100 can operate with a process gas flowrate of up to 100 kg/h at an inlet temperature of 200°C. For many products, this means a 30% increase in powder production compared to previous models, says the company. High-performance HEPA filters are available, for food or chemical applications, as well as powder collection-tubes in sizes from 250 to 3,500 mL — *GEA Group, Düsseldorf, Germany*
www.gea.com

Ribbon blenders designed for easy cleaning

The Model 42N-18SS ribbon blender (photo) is crafted from type 316 stainless steel with interior surfaces polished to a 150-grit finish for easy cleaning. With a maximum working capacity of 18 ft^3, the blender is direct driven by a 10-h.p. gearmotor for processing materials with a bulk density of up to 60 lb/ft^3. The agitator is a solid double-ribbon design, suitable for center discharge, with internal flanges welded to shaft-stub ends and a heavy-duty anti-friction bearing on the non-driven end. A two-piece safety grating with ½-in. perforations ensures safe operation while the split folding covers are open. The finished product is discharged through a pneumatically-operated, 4-in. dust-tight knife gate valve. — *Charles Ross & Son Co., Hauppauge, N.Y.*
www.mixers.com

Advanced borescopes provide more precise inspections

The new VJ-4 dual-camera video borescope (photo) is available in four sizes: 2.5, 3.9, 6.0 and 8.0 mm. All VJ-4 models are equipped with a 5.5-in. QLED screen with 2.5x digital zoom, a touchscreen or stylus interface with on-screen annotation and an industry-first mini joystick, which provides precise control of the articulating tip. The articulating borescope provides high-quality video inspection with an advanced relative measurement function. The device's six-stage LED illumination is easily adjustable with ten different brightness levels, which helps to provide clearer inspection images. — *ViewTech Borescopes, Traverse City, Mich.*
www.viewtech.com

A new spray nozzle for thick or particulate-laden media

This company's new HollowStream liquid atomizing spray nozzle (photo) provides a hollow-cone spray pattern, and features a tangential flow design. The design is vaneless, with wide-open internal features, to resist clogging while producing a uniform distribution in a ring pattern with medium to large droplets to solve cooling, cleaning, foam breaking, rinsing and dust-suppression application. With HollowStream nozzles, the liquid is supplied into the body of the nozzle, creating a swirling action within a vortex chamber. This vortex produces the spray pattern when the machined nozzle breaks the liquid surface tension as it exits the orifice and into a controlled spray angle. The open, right-angle design is compact and appropriate for applications involving liquids that are thick, or containing particulate matter. The nozzles' stainless-steel construction adds to their durability and corrosion resistance. — *Exair LLC, Cincinnati, Ohio*
www.exair.com ■

Mary Page Bailey and Gerald Ondrey

Preventing Leaks in Small-Diameter Piping

Department Editor: Scott Jenkins

Leakage can negatively affect operations in pilot plants and laboratory units, and can affect a wide range of laboratory equipment, analytical instruments and testing equipment. This one-page reference offers information on common causes of leaks in small-sized piping systems and their prevention.

Table 1 outlines some of the major causes and sources of leaks in small-bore piping systems.

TABLE 1. COMMON CAUSES AND SOURCES OF LEAKS IN SMALL-BORE PIPING

Improper assembly	• Undersized wrenches require more force in connecting pipes. Sufficient force is often not supplied • If upstream and downstream fittings are not properly held, they may slip before the necessary turns have been completed • In an effort to reach desired alignment, fittings may not be tightened all the way. To get fittings to match up, they are often tightened insufficiently (connection may be too loose) or forced into place (creating unecessary stress)
Poorly applied pipe sealant	• Inexpensive (and lower-quality) sealant may have been used • Sealant material may have been applied too lightly or unevenly • Tapes may have been allowed to bunch up due to poor assembly
Badly threaded pipe fittings	• Dies for threading pipes are often used well past their lifetimes, resulting in rounded threads that are difficult to seal • When standard dies are used to thread high-alloy pipe, they wear out quickly • Dies not started carefully enough result in threads that are not true • Pipe threads can be cut too short or too long to fit an exact dimension
Compression fittings are not tightened properly	• Pipe fittings are often tightened by "feel" instead of by the number of turns • Many are deliberately under-tightened for longevity • Compression fittings that are routinely removed and replaced can leak • Under-tightened compression fittings are aimed at extending life, but can lead to leaks
Tubing inserted improperly	• Tubing that is not inserted all the way into the fitting will result in a poor seal
Debris and scratches	• Dirt, grit or foreign materials can cause gaps or scratches on fitting sealing surfaces and tubing outside surfaces are not generally treated • Tubing is often scratched from being dragged along floors
Misalignment	• Ferrules are left out, damaged, or badly misaligned, compromising sealing • Tubing that is placed in at an angle or forced into the fitting in such a way that the resulting forces are working against the fitting itself can promote leakage
Tubing hardness	• In compression fittings, the ferrules must be harder than the tubing, so they can bite into it (compress) and seal effectively • Tubing from local suppliers sometimes has no reference to maximum recommended tubing hardness, resulting in tubing that is too hard
Temperature changes	• Large (>150°C) or rapid (>25°C/min) temperature swings can cause leakage in as little as one cycle • While slower and of less magnitude, ambient temperature swings happen with higher frequency, and can also be a problem • Common problem areas include pipes that are outdoors, in non-air-conditioned process bays, and facilities with significant off-hours temperature changes
Stress and torque	• Pipe fittings that are subject to higher stresses and torque tend to leak more easily because these forces work against the sealing surfaces over time • Turning a poorly supported valve can loosen the fitting and cause leaks • Vibrations, bumps and similar shocks from equipment and operations all can contribute to leakage
Clearance issues	• Insufficient clearance for pipe threads, unions and compression fittings when connecting and disconnecting can lead to improper tightening, bent tubing or piping that has been forced together • Flanges and sanitary fittings that are pulled apart to make gasket access easier stress nearby fittings

Guidelines to minimize leakage

The following practices will help reduce the likelihood of pipe leakage.

Buy quality components. Components with lower initial costs usually cost more when the costs of finding and repairing leaks are included. Quality always costs more, and many very low-cost fittings are sold primarily on price and are often of poor quality.

Select the proper components for the service. Make sure the tubing you purchase has the proper hardness. Confirm that all the piping components have an adequate pressure and temperature rating with an adequate margin above your highest operating conditions.

Assemble fittings properly. Train personnel on proper assembly techniques. Leaders should not assume that all personnel know how to assemble fittings correctly, or that they will carefully read the (often cryptic, or missing) instructions. Gauge compression fittings after assembly to confirm proper makeup. This pays rich dividends, showing which fittings need to be tightened.

Gauge compression fittings after assembly to confirm proper makeup. Mark the fitting to indicate the proper number of turns or have a way to count them. Make sure the tubing is fully inserted into a compression fitting by marking the proper insertion depth.

Consider leakage in the design. Avoid problematic connections, such as pipe threads and pipe unions, particularly in heated or cooled lines or in gas service. Consider where flanges may be a better choice on larger lines and compression fittings on smaller lines. Isolate vibrating equipment with damping pads or springs. Carefully design systems subject to temperature changes. Consider custom fabrications to reduce the number of potential leak points.

Use holdbacks. Use holdbacks to keep adjacent fittings from being needlessly turned or stressed. Train personnel how to use them properly.

Minimize the number of joints. Bend more tubing instead of using elbow fittings. Use crosses instead of dual tees (four versus six potential leak sites). Purchase reducers that match exactly the sizes you need rather than using multiple fittings

Properly mount equipment. Make sure the mounting provides adequate strength to resist the forces that will be applied to it. ■

Editor's note: The content in this column is adapted from the following article: Paluzzi, R., Leak Prevention in Small-bore Piping and Tubing, *Chem. Eng.*, October 2020, pp. 22–25.

Applying Location Factors for Conceptual Cost Estimation

A practical overview on how to use location factors, and some tips on when to use — or not use — them

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Often in the early stages of project development in the chemical process industries (CPI), the development team is presented with the task of estimating the cost to build a plant or a system at different locations (Figure 1), be it because of macro-location decisions (for example, evaluating different locations to develop a project), or because cost data are available at a location separate from where the project will be developed. In this context, location factors can be a valuable tool for the project development team to generate cost estimates when the engineering design has not started, or is in its early (visualization or conceptual engineering) phases.

This article describes location factors used in cost engineering, how they are developed and when they should be used. It also highlights some of the caution that needs to be taken when employing them, and presents some of the manners in which they can be utilized along with examples.

Location factor basics

A location factor can be defined as "*an instantaneous (that is, current — has no escalation or currency exchange projection) overall total project factor for translating the total cost of the project cost elements of a defined construction project scope of work from one geographic location to another. This factor recognizes differences in productivity and costs for labor, engineered equipment, commodities, freight, duties, taxes, procurement, engineering, design, and project administration. The cost of land, scope/design differences for local conditions and codes, and differences in operating philosophies are not included in a location factor*" [*1*].

Location factors involve various elements, such as geographic, economic and environmental factors. These play a key role in assessing project viability, reducing risk, making strategic decisions and ensuring accurate cost estimates. Location factors include labor rates, local productivity, taxes, utility costs and regulatory compliance costs. Labor rates can vary due to regional wage disparities, while workforce productivity is influenced by education and training. Taxation policies impact project expenses, and regulatory environments require compliance adjustments. Utility costs fluctuate based on local infrastructure and energy sources. Proximity to raw-material suppliers affects supply chain efficiency. Transportation costs depend on logistics and access to distribution centers. Real-estate costs vary by location, while climate, economic conditions, political stability and cultural factors play essential roles in cost estimation and project planning. Understanding these location factors is essential for accurate cost estimation and project planning in different types of projects and industries.

Location factors are intended to be used when there is absence of quotes for equipment, labor or materials at a project. That is, they should only be used during preliminary project cost assessment, such as Class 5 (+100/+30% accuracy on the high side and –50/–20% on the low side) or Class 4 (+50/+20% accuracy on the high side and –30/–15% on the low side) estimates for screening, conceptual engineering or feasibility study purposes. Location factors should not be used for Class 3 (+30/+10% accuracy on the high side and –20/–10% on the low side) or better estimates.

Given the difference in weights relative to equipment, labor, piping, electrical, civil/structural or other cost items in the overall cost of a project between different industries, location factors can vary significantly from industry to industry (that is, different industries may yield different location factors). Location factors developed specifically for a particular industry should be preferred to general location factors that encompass a broad range of project and industry types.

Care should be taken when using location factors, as they may not reflect recent changes in local conditions, such as currency exchange, new laws and regulations, temporary logistics constraints, material or labor shortages, or inability to manufacture specialized equipment or components at the selected location. The cost engineer should verify data quality, minimize subjectivity, encourage consultation with experienced professionals, and recommend sensitivity testing to gauge the impact of location factors.

Location factors can be obtained by the following methods:

- Comparing the actual cost of two similar projects built on separate locations
- Comparing the actual cost of a project built on one location against an estimate of building a similar project at a different location
- Comparing cost estimates for two similar projects on separate locations
- Factoring in differences in local

TABLE 1. SOME SOURCES FOR LOCATION FACTORS OR INDEX DATA

Data source	Applicable to
Intratec Solutions, LLC *[2]*	Chemical process industries
Compass International Inc. *[3]*	Different types of industry or infrastructure projects
Cost Engineering *[4]*	Chemical process industries
Department of Defense *[5]*	Defense facility projects
BNi *[6]*	Building construction

Note: this is neither an exhaustive list, nor does it give an indication of the relative accuracy of each database.

rates, taxes, productivities and so on, between two locations

The first three methods rely on having recent cost data on projects of a similar scope, which limits their applicability. Cost-to-estimate and estimate-to-estimate methods have the added difficulty of trying to reconcile differences in risks, contingency, or other aspects considered between different estimators.

The factoring method, on the other hand, breaks down the project into individual components, such as equipment, engineering, labor, piping materials, civil/structural materials, and so on, assigns weights to each component based on a typical cost composition for a project in a given industry at a reference location, and then proceeds to compute location factors given a specific set of local inputs, such as commodity prices, labor rates, productivity, taxes, currency exchange, freight rates, or others. This method has the advantages of not requiring cost data for a specific scope to exist at the location of the project, and being more convenient to update to reflect changes to local conditions. To develop up-to-date location factors, cost engineers will need to survey accurate data for each of the locations being assessed.

Some organizations engage in cost-data collection in order to compute up-to-date location factors to be used in conceptual estimating. Table 1, while not an exhaustive list, provides some references where location factor data can be consulted. Other commercial estimating software include databases of their own, or have built-in models to adjust cost estimates based on local cost inputs.

Assessing project cost

The most basic expression to utilize location factors to estimate the cost of a project at a new location based on the cost of a project of similar scope and capacity at a reference location is as follows:

$$C_n = fC \qquad (1)$$

Where:
C_n = capital investment at location n
f = lumped cost-index factor relative to the original installation location
C = original capital investment

Where location factors are available from a reference for both the new and the original location, the lumped cost-index factor relative to the original installation location can be calculated as follows:

$$f = f_n/f_R \qquad (2)$$

Where:
f_n = location factor for new location
f_R = location factor for original project location

If the new project has a different capacity than the original project, Equation (1) can be combined with a capacity-cost correlation, as shown on Equation (3) [*7*]:

$$C_n = f[D(R)^x + I] \qquad (3)$$

Where:
D = direct cost of the original project
R = capacity ratio between new and original project = production capacity of new project / production capacity of original project
x = Cost-capacity exponent (usually between 0.6 and 0.7 for process facilities where the capacity is increased by increasing the size of process equipment, and approaching 1.0 for process facilities where the capacity is increased by adding identical units or modules).
I = the total indirect cost for the original project

If a distribution of equipment, material and labor costs is known for the original project, and separate cost indexes can be determined for each relative to the original location, then Equation (4) tends to provide better results when aiming to determine the fixed-capital investment required for a new similar process plant at a new location with a different capacity and similar number of process units [*7*]:

$$C_n = R^x [f_E E + f_M M + f_L f_F e_L (E_L + f_y M_L')](f_I)C/(C - I) \qquad (4)$$

Where:
E = Equipment cost
$f_E E$ = current equipment cost index relative to cost of the purchased equipment
f_M = current material cost index relative to cost of material
M = material cost
f_F = cost factor for field labor
f_L = current labor cost index in new location relative to E_L and at M_L' old location
e_L = labor efficiency index in new location relative to E_L and at M_L' at old location
E_L = purchased-equipment labor cost
M_L' = labor employee-hours for specific material
f_y = specific material labor cost per employee-hour
f_i = indirect cost index
C = original capital investment

Equation (4) has the advantage of taking into account differences in equipment, material and labor costs composition specific to the type of facility being constructed.

The following examples illustrate the use of Equations (3) and (4) when estimating the costs of a new facility, using reference data from a project at a different location.

Example calculations

Example 1 — Use of lumped factor. A chemical process facility with a capacity to produce 10,000 units per day was just built at Location A at a cost of $30 million ($25 million direct cost plus $5 million indirect cost). Upper management would like an order-of-magnitude cost of building a similar facility with a capacity to produce 5,000 units per day at Location B. Previous project experience has indicated that: a) projects at Location B are 20% more expensive than at Location A, and b) direct

CAUTION WHEN USING LOCATION FACTORS

Location factors:

-Should only be used for Class 5 and Class 4 estimates

-Do not account for differences in cost of land, scope, local conditions, codes or operating philosophies

-Can be significantly different from industry to industry: That is, different industries will have varying compositions of equipment, materials, labor, structures and so on

-May not be up-to-date to reflect recent changes in local conditions, such as currency exchange, new laws/regulations, temporary logistics constraints, material or labor shortages

costs for similar-type facilities escalate at a capacity-cost exponent of 0.67. Assuming that indirect costs remain equal independently of plant capacity, and neglecting inflation in the calculation, estimate the cost of the new project.

Solution. The capital cost of the new project can be estimated using Equation (3) with the following inputs: f = 1+20% = 1.20; D = $25,000,000; R = 5,000/10,000 = 0.5; X = 0.67; I = $5,000,000. Then:

$$C_n = f[D(R)^x + I] = 1.20[25,000,000(0.5)^{0.67} + 5,000,000] = \$24,855,201$$

A new facility of 5,000 units per day capacity built at location B would cost in the order of $24.9 million.

Example 2 — Use of separate cost indexes for equipment, materials and labor. A chemical process facility with a capacity to produce 10,000 units per day was just built at Location A at a cost of $30 million ($12 million for equipment, $7 million for materials, $6 million for labor, $5 million indirect cost). Upper management would like an order-of-magnitude cost of building a similar facility with a capacity to produce 5,000 units per day at Location B. Previous project experience has indicated that: a) direct costs for similar-type facilities escalate at a capacity-cost exponent of 0.67, b) equipment costs 30% more in Location B than Location A, materials costs 5% more in Location B than Location A, labor rates are 30% cheaper in Location B than Location A, labor productivity is 40% lower in Location B than in Location A, and indirect costs are 5% more expensive in Location B than Location A. Assuming that indirect costs remain equal independently of plant capacity, and neglecting inflation in the calculation, estimate the cost of the new project.

Solution. The capital cost of the new project can be estimated using Equation (4) with the following inputs: R = 5,000/10,000 = 0.5; X = 0.67; f_E =1.30; E = $12,000,000; f_M =1.05; M = 7,000,000; f_L = 0.70; f_I =1.05; C = $30,000,000; I = $5,000,000.

In the case of e_L, the labor efficiency index would be obtained as the inverse of the labor productivity index: $e_L = 1/0.6 = 1.6667$.

In the case of labor breakdown, since only the total labor cost is known, then it can be assumed that $(E_L + f_y M_L') = \$6,000,000$.

In the case of f_F, it is not known how costs related to field labor differ between both locations, so it will be assumed as $f_F = 1.0$.

Then:

$$C_n = R^x [f_E E + f_M M + f_L f_F e_L (E_L + f_y M_L')](f_I)C/(C - I)$$

$$C_n = (0.5)^{0.67} [1.30 \times 12,000,000 + 1.05 \times 7,000,000 + 0.70 \times 1.6667 \times 1.0 \times 6,000,000](1.05)(30,000,000/25,000,000 =$$

C_n = $23,718,068.

A new facility of 5,000 units per day capacity built at Location B would cost in the order of $23.7 million.

Final remarks

In conclusion, location factors can be a valuable tool for an organization at an early stage to make "go/no-go" decisions, select a geographical location, or make a broad estimate of the overall project budget without spending significant efforts in engineering, provided the cost estimator takes caution in considering the aspects in the box on this page. There are different methods to obtain them, with factoring having the advantage of allowing cost estimates to be made where previous similar project data is unavailable, and of being more convenient to update to reflect current local conditions. ■

Edited by Gerald Ondrey

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An Introduction to Canned Motor Pumps

Canned motor pumps (CMPs) are designed to prevent emissions by eliminating the mechanical seal. Provided here is an overview of CMPs, along with information on common uses

Stephen Jones
Hayward Tyler Inc.

IN BRIEF

Emissions from process equipment not only pose safety and environmental risks, they also have a significant impact on maintenance costs and lost time of production. The increased focus on limiting emissions from conventional pumps draws attention to the biggest emissions culprit — the mechanical seal.

Sealless pumps do not use a mechanical seal, so the possibility of leaking fluids, dangerous or otherwise, from the seal into the atmosphere is eliminated. This category of pumps offers additional simplicity, by also eliminating coupling alignment, bearing-frame maintenance and auxiliary systems associated with lubricating or cooling bearings (see article on pp. 29–31 of this issue).

The two main categories of sealless pumps are canned motor pumps (CMPs) and magnetic drive (mag drive). CMPs offer increased safety through double containment, a reduced number of bearings (and inherent maintenance costs), and improved reliability when applied properly to the application. This article provides information on the operation and potential benefits of CMPs in the chemical process industries (CPI).

How is the seal eliminated?

Laws of physics dictate that higher-pressure fluids want to move to lower-pressure areas. Because traditional pumps must couple to a driver (motor or turbine), the pump shaft needs to exit the pump pressure boundary (pump case). This means that the high-pressure fluid created by the rotating pump wants to leak into the atmosphere along the shaft, where it penetrates the pump case. In traditional pumps, this leakage is prevented by using gland packing or a mechanical seal.

Canned motor pumps take a different approach, using a common shaft for the pump and motor, and containing it all inside a pressure boundary. This design eliminates the pressure differential across the rotating seal and thereby eliminates the driving force for the fluid to leak. Using a common shaft for the pump and motor gives rise to other benefits also, such as eliminating coupling alignment (both hot and cold), which removes a potential failure point in the pump.

Material considerations

CMPs are constructed of materials compatible with most process fluids, yet the materials are not overly exotic or expensive. The typical metallurgy of the wetted components of a CMP are 304 stainless steel with the stator and rotor cans made from Hastelloy C276. Although Hastelloy C, a nickel-based alloy, is more exotic and expensive compared to 300-series stainless steel, the higher electrical resistivity significantly reduces the “eddy current” losses in the stator can, and to a smaller degree, the rotor can. Overall, using Hastelloy results in increased efficiency of the motor.

Additionally, since the stator and rotor cans are fabricated from a thin material (0.010–0.015 in.) to minimize electrical losses and reactivity, it is important to use strong and highly corrosion-resistant materials. The cans are further supported by the electrical steel lamination along the length of the lamination pack and with heavier-duty backup sleeves at the wire-coil end-turn regions. These support the thin can in dealing with the high internal pressures (up to 6,000 psi/42 MPa) within the motor.

For sealing of joints, there are typically face-to-face gasket designs and O-ring gaskets with a machined groove. For both types of joints used to seal the pump-to-motor and motor-to-end cover mating surfaces, it is important to verify the compatibility of the material with the process fluid. A standard design uses polytetrafluoroethylene (PTFE) gaskets due to their vast compatibility with various process fluids. For higher temperature and pressure applications (above 390°F and 580 psig), a spiral-wound stainless steel is typically used. The grade of stainless steel will be matched to the pump case. For special chemicals or specific applications, other

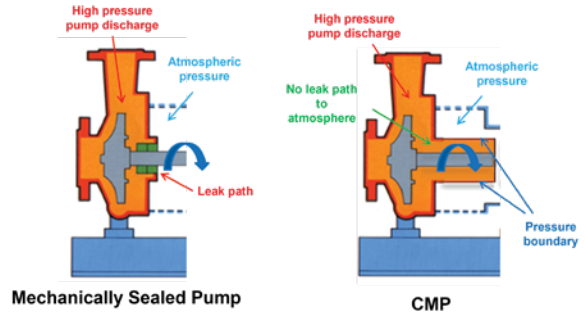

FIGURE 1. The diagram illustrates the difference between a mechanically sealed pump, and a CMP, which has no seal

gaskets may be used and the individual compatibility of those fluids with the gaskets must be assessed.

If using an O-ring joint design, a Teflon-encapsulated Viton O-ring is common, because this type of O-ring provides the corrosion resistance of Teflon (PTFE) combined with the elastomeric resilience of Viton.

An important point to understand in the context of CMP bearings is that they use fluid-film bearings. This means that during operation, the rotating surface of the shaft (or shaft sleeve) does not come into contact with the stationary bearing. Instead, as the shaft rotates, it creates a fluid film and the fluid is forced between the shaft and the bearing.

The typical design uses a hardened polished-metallic surface on the rotor, with a softer corrosion-resistant bearing material. The bearing material is designed to be easily replaceable during periods of maintenance. The bearing material used for CMPs is generally either one of two materials: graphite or silicon carbide. Graphite grades typically offer a softer, more forgiving bearing that is more tolerant of particulate matter and upset conditions. However, it will not last as long as silicon-carbide grades. Conversely, silicon carbide, being a harder material, will last longer in the right application, but is less tolerant of particulate wear and upset conditions. One material is not necessarily better than the other for CMP bearings, and material selection should be based upon the application and user requirements and preferences. Other materials, such as PEEK (polyetheretherketone) and other composites, can also be used, but are less common.

Motor fluid properties

When considering the bearing lubricity and motor cooling, it is necessary to understand the requirements and characteristics of the canned motors as they relate to the fluid properties. Typically, the pumped fluid lubricates the bearings and cools the motor. In some instances where the pumped fluid is not compatible with the motor (because of high levels of particulate matter, viscosity issues and so on), then a barrier fluid can be used in the motor.

The motor fluid must have appropriate viscosity to provide adequate lubrication of the hydrodynamic bearings, yet also have sufficient flow through the motor to cool the parts effectively while minimizing fluid-friction drag losses. As a general rule, fluids with an absolute viscosity greater than 200 centipoise and less than 0.07 centipoise are not desired.

An alternative solution when the pumped fluid cannot be used inside the motor involves a barrier fluid. A labyrinth seal is used to isolate the pump, and the motor is filled with a compatible fluid that is different than the pumped fluid. It should be noted that, in some cases, an internal mechanical seal is used. This seal does not leak to the atmosphere, but instead, leaks a small amount of motor fluid into the pump end.

With either sealing option, it is essential to ensure the compatibility of the motor (barrier) fluid with what is being pumped. As previously mentioned, the fluid inside the motor is used to cool the motor, as well as to lubricate the bearings. The fluid will therefore increase in temperature as it circulates through the motor. As the fluid temperature increases, so does the fluid vapor pressure (and typically, the viscosity decreases), for these reasons, it is important to evaluate the thermodynamic properties of the motor fluid and ensure it will not vaporize ("flash") in the motor. This might cause vapor lock or insufficient bearing lubrication.

The temperature rise of the motor fluid is not only a function of the amount of waste heat generated by the motor's inefficiency, but also of the specific gravity, specific heat (heat capacity) and the flowrate of the fluid through the motor. In addition, the thermal conductivity of the fluid will affect the heat-transfer rate from the motor and ultimately, will affect the temperature rise of the motor windings. Motor winding wire has an insulation class determining the maximum temperature to which the wire can be exposed. Typically, CMPs use Class H (180°C) or Class N (200°C) wire, although other ratings are available. Note that class designations for those above Class H are typically specified in International Electrotechnical Commission (IEC; Geneva, Switzerland; www.iec.ch) standard IEC 60085.

Taking this into consideration, there are six main fluid properties of the motor fluid that are to be considered for a given application. These are the following: 1) specific gravity; 2) specific heat; 3) viscosity; 4) vapor pressure; 5) freezing point; and 6) thermal conductivity. Because the viscosity and vapor pressure of some fluids can vary significantly with temperature, it is a best practice to understand these properties at various temperatures. This would generally be at normal-operating, minimum-operating and maximum-operating temperatures. It is worth noting that most manufacturers have a wealth of knowledge on various commonly pumped fluids, so they will likely be able to offer support in defining these parameters if they are unknown at the specification stage. The viscosity and vapor-pressure properties do

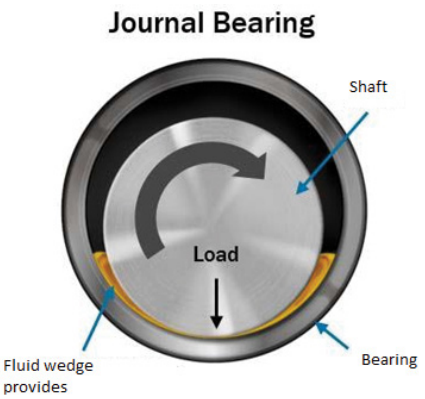

FIGURE 2. In a fluid-fiilm bearing, the pump shaft does not come into direct contact with the bearing

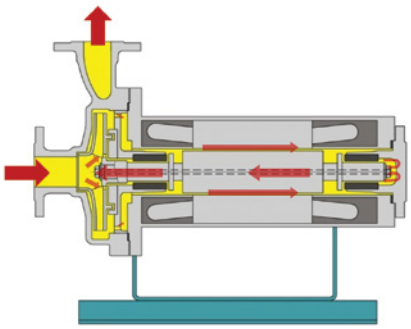

FIGURE 3. The Plan 1-S circulation, shown here, is the most common type of circulation path for a CMP

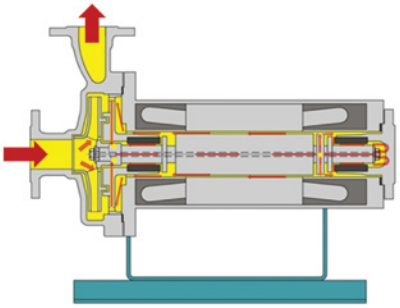

FIGURE 4. This diagram shows Plan 1-SD circulation, which is used for handling volatile fluids

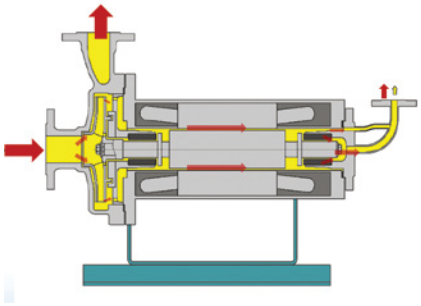

FIGURE 5. Plan 13-SE reverse circulation, shown here, is used when pumping fluids with low vapor pressure

not vary linearly with temperature, so the three points mentioned can be used to generate an approximate curve, allowing these values to be calculated for other temperatures.

Motor circulation flow paths

There are a variety of fluid flow paths for circulating fluid through the motor. Most manufacturers adopt those specified in the American Petroleum Institute (API; Washington, D.C.; www.api.org) standard 685 (Sealless Centrifugal Pumps for Petroleum, Petrochemical, and Gas Industry Process Service-Annex D). This standard outlines 14 different flow plans. Those familiar with mechanical seal plans will be accustomed to this concept. All these plans will not be reviewed in this article, however, the most widely used circulation plans are discussed. It is not an expectation that the user would identify the model type and circulation plan for their application. This would be done by the manufacturer's application engineers. However, there are considerations that users should take into account when specifying a CMP, for example, the availability of cooling water (when pumping a hot liquid) or the availability of pipework to route back to a tank (for low-vapor pressure fluids).

Plan 1-S Internal circulation (hollow shaft). This is the most common circulation plan and involves a small amount of the pump discharge circulating through orifices in the pump-end (PE) bearing housing and into the motor (Figure 3). It travels through the

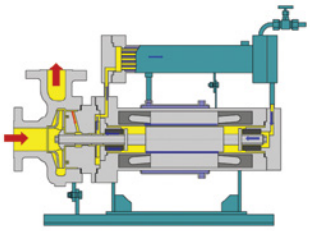

FIGURE 6. This diagram shows Plan 23-S circulation, which is used for high-temperature fluids, such as heat-transfer fluids

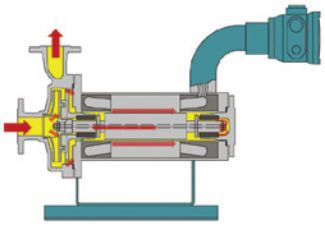

FIGURE 7. The circulation plan shown here is the same as that shown in Figure 3, but with added insulation for handling high-temperature fluids

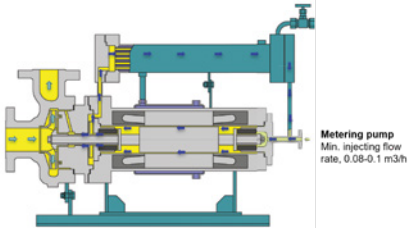

FIGURE 8. The circulation plan shown here is designed for pumping slurries and abrasive fluids

pump-end bearing, across the rotor and then through the cover-end (CE) bearing before returning to the suction via the hollow rotor shaft.

Plan 1-SD Pressurized circulation. This circulation plan (Figure 4) is used for handling volatile fluids that have a low boiling point. The premise is that the auxiliary impeller adds pressure to the motor cooling fluid to prevent it from vaporizing inside the motor. The flow path starts from the pump discharge and travels through ports to a hole in the hollow shaft. It travels through the hollow shaft to the eye of the auxiliary impeller. The flow splits and some goes through the CE bearing and back to the auxiliary impeller. The rest travels past the rotor, through the PE bearings and back to the discharge side.

Plan 13-SE Reverse circulation. This circulation plan is used when pumping fluids with low vapor pressure, such as refrigerants, liquefied gases, ammonia and so on. The fluid is circulated only once through the motor to avoid excessive heat pick up in the fluid (which could cause cavitation). As discussed previously, any vapor inside the CMP can do significant damage to the bearings and other internal parts.

The flow path (Figure 5) is from the pump discharge through holes in the PE bearing housing, through the PE bearing, across the rotor, and through the CE bearing before exiting the motor at the cover end. The fluid would typically be returned to a suction tank or collection manifold.

Plan 23-S Externally cooled motor. This circulation plan is used when pumping high-temperature liquids (for example, heat-transfer oils). This circulation uses a heat exchanger to cool the motor fluid. The same fluid being pumped is used inside the motor, just at a lower temperature. The design uses a thermal barrier to thermally isolate the hot pump end from the cooler motor. This circulation requires site-supplied cooling water, or it can use an air heat exchanger, although this is less common. Generally, a small amount of fluid circulates from the impeller discharge, through the thermal barrier, and toward the heat exchanger inlet. The motor fluid circulates through the heat exchanger at the PE and then enters the motor at the CE (Figure 6). It passes through the CE bearings, across the rotor, and through the PE bearings before repeating this circuit. There is sometimes an auxiliary impeller keyed to the shaft to help circulate the motor fluid, which can be located at either of the bearing-housing ends.

Plan 1-S High temperature, no cooling. Although this flow plan uses the same circulation path as mentioned first, it is worth mentioning as an option for pumping high-temperature fluids when there is no site cooling available. This motor design uses an advanced grade of insulation (Class 400) for handling higher temperatures. This motor configuration is typically only available up to 120 hp and is often not rewindable (Figure 7).

Plan 53-S and 54-S slurry handling. This circulation plan is suitable when pumping slurries or abrasive fluids that do not provide good lubrication and cooling to the motor. This plan (Figure 8) uses a barrier fluid inside the motor. The barrier fluid is circulated through the motor, either originating from a seal pot (53-S) or an external source (54-S). A labyrinth seal (or internal mechanical seal) separates the pump end from the motor. An external metering pump is commonly used to ensure that the motor pressure stays above the pump discharge pressure. The compatibility of the motor fluid and the pumped fluid must be checked, because a small amount will leak from the motor to the pump across the internal labyrinth seal/mechanical seal.

Concluding remarks

When investigating the use and benefits of a CMP, whether a new installation or a retrofit of an existing pump, it is essential to know the fluid properties and operating conditions. All analyses must include expected abnormal or possible upset conditions, which can affect the performance and reliability of the pump. This requires a mutual understanding of the application considerations by the system designer, end user and by the CMP manufacturer. With this approach, a cost-effective and reliable installation will be realized.

CMPs offer the safest and most environmentally friendly pumping option when handling fluids that can harm the environment. CMP use is rising with environmental concerns, combined with features that eliminate the most common pump failure modes. Eliminating the mechanical seal, removing the requirement for hot and cold alignment, and reducing the number of bearings plus lubrication systems offer a reliable and maintenance-free pumping solution when correctly applied to the application. ■

Edited by Scott Jenkins

Editor's note: All images courtesy of Hayward Tyler

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Building Better Seal-Support Systems for Pumps

Adhering to API 682 guidelines will create safe, efficient and effective mechanical-seal supports in pumping systems

Brian Rudary
Swagelok Co.

IN BRIEF

In the 1980s, mechanical seals became the most frequently used sealing technology in petroleum refineries and chemical plants. The American Petroleum Institute (API; Washington, D.C.; www.api.org) responded by establishing a committee to write standards for the components. In 1994, API published guidelines including API 682, Shaft Sealing Systems for Centrifugal and Rotary Pumps, and noted the following:

"*This standard is designed to default to the equipment types most commonly supplied that have a high probability of meeting the objective of at least three years of uninterrupted service while complying with emissions regulations.* [*1*]"

The standard also included a stipulation that facilities should default to technology that has been proven to be safe and reliable unless otherwise specified. Now in its fourth iteration (published in 2014), API 682 remains the standard for mechanical seals and their support systems.

Though API 682 remains primarily a mechanical seal standard, it also provides guidance on seal support systems (Figure 1) because they are crucial to ensuring that a seal and pump system operates properly. It is important to understand whether your seal-support-system supplier adheres to the standards laid out in API 682 4th Edition. These best practices, outlined in this article, will help to ensure seal support systems function at peak performance. Following these guidelines during system design and construction can increase reliability and safety while reducing costs.

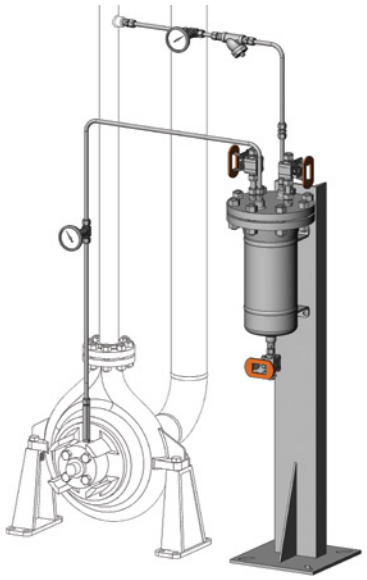

FIGURE 1. The use of high-quality components can make it much easier to maintain seal support systems and keep them operating at peak performance, such as this API Plan 22 cooled flush system with a strainer

Minimizing potential leak points

Much of the focus of API 682 4th Ed. is on keeping potential leak points from occurring through the reduction of seal-support-system connections. To further emphasize this point, the standard suggests avoiding threaded systems, whether with welded pipe or tubing. Since each connection may leak if not properly constructed, reducing the number of connections is essential. The more connection points there are in any seal support system, the greater the potential to reduce its long-term reliability and result in greater risk for asset damage, increased downtime, environmental issues and safety risks.

Historically, seal support systems used pipe because it was the preferred method of construction. Over time, however, that has changed. Today, more seal manufacturers, end users and pump manufacturers prefer tubing rather than pipe because it has been established as a more reliable option in multiple crucial industrial applications. Though many specifiers still opted for hard pipe, API 682 started endorsing tubing instead of piping for many situations. In the current 4th Edition, tubing and pipe are specified interchangeably as preferred methods for seal support systems.

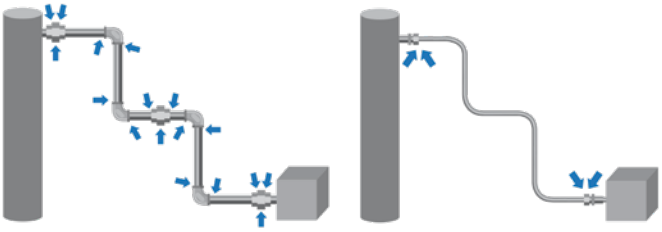

FIGURE 2. When possible, tubing (right) is preferable to threaded pipe assemblies (left) because it reduces the potential for leaks. In this example, using tubing strengthens the run with bends and reduces the number of potential leak points from 17 to 4

Tubing offers significant advantages over traditional hard pipe. It naturally reduces the number of connections required by bending lines and using adapters. On occasion, the number of connections can be reduced to two — one at the seal and one at the sealing system (Figure 2). Additionally, annealed tubing can be bent in such a way that it strengthens the tube at the bend and hardens the metal. Today's connection technologies, such as flange adapters and extended male connectors, also reduce the number of connection points. By eliminating threaded ports on seals and seal pots, multiple fittings become unnecessary. Tubing also saves operational expenses by reducing the maintenance, repair and operation (MRO) costs on the pump, seal and support system. As tubing replaces pipes, onsite welding — a significant cost associated with traditional piping — is no longer required, which additionally increases the system's uptime.

Designing seal support systems

Optimal seal and pump operation depends on properly designed seal support systems. Using preventive maintenance principles, the seal support systems should be visually inspected regularly. Making inspections easier can keep systems functioning more reliably and safely. An intuitively designed seal support system can support these inspections and should follow the best practices outlined in API 682 4th Ed., described in the following sections.

The system's function should be apparent and the design intuitive. The sudden stopping and starting of pumps can damage mechanical seals if they are not supported properly. That is why well-designed seal support systems allow for streamlined operation and the elimination of common mistakes during pump commissioning.

In API 682 4th Ed., a Plan 32 arrangement is shown as multiple instruments and components installed on either piping or tubing. Though this makes sense from a functional perspective, it prevents operators from understanding how the system operates, what information is important to gather and what makes information critical. Poorly placed seal support systems — such as putting them next to the pump's seal — complicate the process of reading instruments that operators must examine to make sure the pump is functioning correctly. Putting even the smallest obstacle between operators' line of sight and seal support systems can lead to reduced reliability. One method frequently used to solve the problem is to arrange the components on a panel (Figure 3).

Placing a piping plan, such as a Plan 32 layout, on a panel accommodates two important design principles: proper identification and operation (Figure 4). This provides several benefits. First, the Plan 32 now looks like a distinct system. Instead of only having components located on a pipe or tube run, they are laid out on a panel where the flow path can be identified, and all instruments are available at eye level.

Additionally, API 682 supports these design considerations. It states: "*All controls and instruments shall be located and arranged to permit easy visibility by the operators, as well as accessibility for tests, adjustments and maintenance.* [*2*]"

Lastly, panels can include part numbering information, flow path indication and operator instructions. These improvements help ensure safe and reliable startup and shutdown of pumps and seal support systems.

The system should be designed for ease of maintenance. Ensuring that your seal support system operates properly is critical, but it is not the only consideration as you design your system. The system should also be simple to maintain. Many of its components, including flowmeters, strainers and other visual instruments, should be included in preventative maintenance (PM) plans, and the maintenance must be safe and simple for maintenance personnel to do. For example, improperly placed strainers may eliminate the possibility of blowdown, significantly reducing the likelihood that PM will be done at recommended intervals.

In addition, block-and-bleed configurations are recommended for gages in API 682 4th Ed. (Figure 5). Without this feature, gages are more likely to fail and leave operators without the crucial information they need to perform necessary maintenance. In fact, they may not be able to obtain the information until the next turnaround or when the gage is replaced when the pump and support system are decommissioned.

Finally, using tube connections and creative designs leads to systems that are much more easily serviced and replaced without shutting down the entire system. For example, API 682 4th Ed. notes that "*local operation, venting, filling and draining [of seal pots] shall be accomplished from grade. Unless otherwise specified, systems that require the use of a ladder or steps, or that require*

FIGURE 3. Panels with the seal-support-system components attached make it much easier for operators to maintain the system, make sure it is functioning properly and locate components

FIGURE 4. A Plan 32 piping arrangement on a panel allows for easy identification of system components and smoother operation of the system

FIGURE 5. Block-and-bleed configurations on gages are strongly encouraged in API 682 4th Edition. This arrangement makes it easier to replace gages without shutting down the entire system

climbing on the baseplate or piping are not acceptable (8.1.8). [*2*]"

Depending on the age of your facility, the seal pot may only have a pipe plug at the top, which would require the operator to use a ladder in connection with its maintenance. This is unsafe, because operators may be exposed to toxic process vapors.

Optimized seal support systems

Following the design best practices listed in this article can improve reliability and reduce the operating costs of your mechanical-seal support system. Achieving the best results from your system requires paying special attention to the following principles:

• When possible, use tubing instead of welded pipe. This simple design decision can reduce the costs of installation and maintenance. It will also reduce the number of potential leak points, making for a much more reliable system

• Minor instrumentation issues or filling seal pots should not require the shutdown of the pumps. If the system allows, components should be mounted on panels with proper labeling and design. This will make the system easier to maintain and lower the chances that an operator will accidentally damage seals

When choosing a supplier for your seals and seal support systems, make sure the supplier has the capability to design and assemble them in ways that benefit your specific operating conditions. Suppliers should have local, reliable design centers that can provide support with reduced costs, time savings and improved safety. They should also be able to advise on the best way to create a seal support system that works for your organization.

Having seals fail is a significant concern to rotating equipment in any facility, in part because they are expensive to repair. Using the design principles and best practices outlined in the API 682 4th Ed. standard reduces those costs and provides more peace of mind when dealing with seals and their support systems. ■

Edited by Mary Page Bailey

All images provided by Swagelok Co.

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The Chemical Regulatory Landscape: Navigating Compliance Challenges

Achieving regulatory compliance is often viewed as overly complicated or restrictive, but a good understanding of the current regulatory landscape can help fuel business growth and efficiency

Dave Haase
ChemDirect

When talking about modern manufacturing, few sectors experience as much regulatory scrutiny as the chemical process industries (CPI). These regulations, with their dynamic and ever-evolving nature, are frequently seen as both protective and perplexing. As the CPI often handle a wide range of products (some of which can be toxic or hazardous), such regulations are essential to protect the environment, public health and even the integrity of global markets (Figure 1).

Yet, for professionals working deep within industrial confines — especially engineers involved in chemical processing — these guidelines often present intricate challenges that need untangling.

Understanding these regulatory intricacies is more than just a professional requirement. It is the cornerstone for ensuring that the CPI not only remain compliant, but also continue to thrive. With shifts in global policy, technological advancements and emerging research, this landscape is constantly changing, emphasizing the necessity for professionals to stay informed and adept.

For industries as dynamic and varied as the CPI, the regulatory landscape serves as both a guide and a guardian. Understanding this landscape is not just about adhering to the rules, but about recognizing its integral role in shaping effective businesses. At first glance, regulatory compliance might seem restrictive — a set of rules limiting what businesses can do. However, when approached strategically, it can be a springboard for innovation, efficiency and growth.

This article seeks to shed light on this regulatory landscape, providing practical guidance for those at the frontline of chemical processing and emphasizing the pivotal role they play in blending compliance with business growth.

Key regulatory bodies for the CPI

Navigating the regulatory maze of the CPI begins with a clear comprehension of the key organizations involved, their interaction among each other and the domains they oversee. Several such regulatory bodies are described below.

International regulatory bodies. At the apex of global oversight, entities like the United Nations Environment Program (UNEP; Nairobi, Kenya; www.unep.org) and the International Council of Chemical Associations (ICCA; Arlington, Va.; www.icca-chem.org) hold significant sway. The UNEP, for instance, plays a pivotal role in setting environmental benchmarks and promoting sustainable chemical practices on a global scale. Simultaneously, the ICCA brings together chemical associations from various countries, aiming to provide a unified voice on matters of global chemical safety and stewardship.

National regulatory bodies. Drilling down to the national level, organizations such as the U.S. Environmental Protection Agency (EPA; Washington, D.C.; www.epa.gov) and the European Union (E.U.)'s European Chemicals Agency (ECHA; Helsinki, Finland; www.echa.europa.eu) come into focus. While the EPA sets and enforces regulations to protect both the environment and human health, the ECHA ensures the safe use of chemicals across E.U. member states. Similar agencies, reflecting the priorities and challenges of their respective regions, operate in numerous countries across the world.

Interaction among regulatory bodies. The balance of collaboration between international and national regulatory entities is a complex one. International standards often serve as guiding principles that national bodies adopt or adapt, based on local needs. However, there are instances where national regulations might influence international standards, especially when pioneering changes are introduced at the country level.

Core regulatory concerns

Across the broad spectrum of regulations, a few areas consistently stand out due to their impact on the CPI, including

FIGURE 1. The wide range of products and processes in the CPI means that achieving regulatory compliance can differ greatly from plant to plant. Thus, organizations must be prepared to generate appropriate strategies to keep employees educated about regulatory requirements

the following:

The environment. With the global emphasis on sustainability, environmental regulations dictate everything from waste disposal to emission standards

Health and safety. Protecting both the workforce and the general public, these regulations encompass safe handling, storage and transportation of chemicals.

International trade. As chemicals cross borders, regulations concerning their trade, including tariffs, import-export standards and international agreements, become crucial (Figure 2).

FIGURE 2. The global reach of the CPI production chain means that companies must stay abreast of both international and local regulations surrounding trade

Regulatory changes and trends

The past few years have seen significant shifts in chemical regulations. For instance, heightened awareness about climate change has led to stricter emissions standards in many countries. Another noteworthy trend is the increasing collaboration between nations to standardize regulations, aiming for a more unified global approach. Procurement has also become a focal point of concern in the context of these regulatory changes. As regulations evolve, the sourcing of raw materials has come under scrutiny [*1*]. Companies are now faced with the challenge of ensuring that their suppliers adhere to both local and global environmental and safety standards. This often means revisiting long-standing partnerships and contracts to ensure compliance with the new normal.

Furthermore, with the emphasis on "green" and renewable chemicals, there is a growing demand for sustainable raw materials. This puts additional pressure on procurement teams to find suppliers who can provide these materials consistently, at the right quality and price. It is a delicate balancing act that requires meeting regulatory demands without compromising on cost efficiency or jeopardizing supply-chain reliability.

The above is especially relevant in the face of global challenges, such as plastic waste in oceans, leading to more conventions and agreements that transcend national boundaries.

Staying up to date

With an intricate web of regulations governing the chemical industry, professionals often find themselves on the frontline of ensuring not just adherence, but also proficient navigation through these guidelines.

Webinars and workshops are an excellent way to remain up to date on regulatory news. Given the dynamic nature of regulations, it is vital to remain in the loop. Webinars and workshops, often organized by regulatory bodies or industry associations, offer timely insights into the latest changes, allowing professionals to ask questions and gain clarity directly from the source.

Industry journals, newsletters and similar publications curated by experts offer detailed analyses of regulatory updates. Regularly perusing them not only ensures awareness but also provides a deeper understanding of the implications of these changes.

Conferences and seminars are a further step forward. Beyond mere information dissemination, attending conferences offers a platform for networking. Here, professionals can share experiences, discuss challenges and brainstorm solutions with peers from various parts of the industry or even the world.

Managing compliance

The following sections describe some suggestions for how companies can effectively manage their compliance efforts.

Internal compliance systems. An efficient internal compliance system acts as the first line of defense against potential compliance breaches. Whether it is software that tracks regulatory changes or a dedicated compliance team, setting up a robust system ensures that the company remains proactive rather than reactive to regulatory shifts.

Staff training. Regulations are not just matters of concern for the top echelons of a company. Everyone, from the factory floor to the boardroom, needs to be aware of the rules that govern their operations. Regular training sessions ensure that all team members are not only aware, but also adept at following and discussing these guidelines.

Cross-functional cooperation. Regulatory compliance is not siloed — rather, it spans multiple departments, from production to human resources, from finance to logistics. Ensuring these departments communicate and collaborate effectively is crucial for seamless and comprehensive compliance.

In essence, effective compliance management is not just a strategic necessity. It is a commitment to ethical operations, sustainable growth and responsible industry leadership.

Overcoming obstacles

Obstacles when dealing with compliance are inevitable. Moving past them in a manner that ensures the organization remains within compliance limitations can get complicated. Below are some considerations to bear in mind.

Resource allocation. Businesses might find themselves stretched

thin when it comes to dedicating resources for compliance. Addressing this issue requires both prioritizing areas of utmost regulatory importance and seeking out efficient tools or external partners that can streamline the compliance process.

Balancing efficiency and adaptation. As new regulations come into play, operations might need adjustments. The challenge lies in making these changes without disrupting efficiency. This calls for innovative solutions, process re-engineering and sometimes even reimagining business models.

Navigating multi-jurisdictional complexity. For multinational companies, compliance is not just about adhering to local rules. They must also grapple with varying regulations across different countries. Developing a centralized compliance strategy, tailored to accommodate regional variations, can go a long way in simplifying this intricate challenge.

While obstacles might seem daunting initially, they can act as catalysts, prompting companies to re-evaluate, innovate and strengthen their operational frameworks. Companies who act accordingly will undoubtedly emerge as the industry's vanguards, setting benchmarks for others to follow.

Integrate compliance & operations

As established previously, in the modern CPI landscape, compliance is not just about ticking boxes. It is an intrinsic component of a company's strategic approach to maintaining a robust, ethical and sustainable operation. Shifting from a view that sees compliance as a burdensome afterthought to one that understands its central role in business can unlock unparalleled efficiencies and opportunities. Incorporating compliance into the very fabric of daily operations demands a proactive and structured approach. Below are some practical steps to achieve this integration.

Regular compliance audits. Just as a health checkup identifies potential ailments before they become critical, regular compliance audits can highlight gaps or inconsistencies in practices. By pinpointing these areas early, businesses can take corrective actions promptly, ensuring they remain on the right side of the regulations.

Proactive project planning. Starting a project with regulatory considerations in mind paves the way for smoother implementation down the line. By weaving in these considerations from the inception of a project or design, businesses can prevent costly alterations or modifications in the later stages.

Integrated compliance roadmap. Having a clear roadmap that marries business objectives with compliance requirements is a game-changer. This integrated approach ensures that as the business grows and evolves, it does so within the bounds of relevant regulations, minimizing risks and uncertainties.

Unified compliance approach. In today's multifaceted organizational structures, ensuring that all departments are aligned in their compliance efforts is crucial. By involving cross-functional teams in compliance tasks, companies foster a sense of shared responsibility, ensuring that every division operates in harmony with regulatory requirements.

Effective internal communication. With regulations continually evolving, it remains vital that all team members are kept abreast of changes. Robust internal communication channels — be it through digital platforms, regular meetings or training sessions — ensure that everyone is informed and equipped to adapt to any regulatory shifts.

As the old adage says: "Prevention is better than cure." This same philosophy holds true for compliance in the CPI. When compliance is viewed as a guiding principle rather than an obligation, it can be transformed from a checklist activity to a strategic asset. Once compliance becomes a part of the daily rhythm, it becomes less of a chore and more of a journey towards building a resilient, ethical and future-ready enterprise.

Growth fueled by compliance

With a robust compliance framework, companies can confidently explore new markets, develop innovative products and streamline operations, all while being assured of their regulatory standing. This not only mitigates potential risks but also carves out a competitive edge in the ever-evolving chemical processing industry.

The only constant in the chemical industry is change. As innovations emerge, markets evolve, and consumer demands shift, so too will the regulations that govern the sector. It is a dance of progression, and to keep pace, continual learning and adaptability are not just recommended — they are essential. Embracing this ethos of perpetual growth ensures not just surviving but thriving amidst the challenges.

At the heart of this compliance-centric approach are the engineers. As the individuals directly interfacing with the tangible aspects of the chemical industry, their role goes beyond mere execution. They are the architects of compliance strategies, shaping them with a blend of technical know-how and regulatory understanding.

Their decisions, innovations and solutions will invariably set the tone for how the industry operates within the framework of regulations, ensuring a balance between innovation and responsibility.

A strategic, integrated approach to compliance will be the linchpin of sustainable success, and at the helm of this journey will be the engineers, guiding the ship with knowledge, expertise and foresight. ■

Edited by Mary Page Bailey

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Author

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An Overview of Non-Combustion Clean Air Technologies

Selecting an effective system for controlling air pollution can help to achieve balance between environmental stewardship and industrial productivity

Anoosheh Oskouian and Anu D. Vij
Ship & Shore Environmental

Air pollution is an ongoing worldwide concern that impacts people and ecosystems across the globe. The emission of pollutants like particulate matter, nitrogen oxides (NOx), sulfur dioxide (SO_2) and volatile organic compounds (VOCs) into the atmosphere has serious health and environmental repercussions, including respiratory illnesses, the formation of smog and climate change (Figure 1). As industries continue to grow and urbanization expands, the need for effective and efficient air-pollution-control systems has never been greater. To address this challenge, a plethora of combustion and non-combustion clean air technologies have emerged as powerful tools in the fight against airborne contaminants.

Many approaches to achieve cleaner air often necessitate extensive changes to existing infrastructure and have limitations in terms of scalability and energy storage. Non-combustion-based clean air technologies present an effective route to achieving cleaner air without relying on combustion-based processes.

This article explores a variety of non-combustion clean air technologies, with special focus on soil vapor-extraction (SVE) systems, chemical scrubber systems, air strippers, oil-water separators, carbon-bed systems and fabric filters (also known as dust collectors or baghouses). These technologies enable companies to strike a balance between environmental stewardship and operational efficiency.

Soil vapor extraction

Soil vapor extraction (SVE) is often employed in the remediation of soil and groundwater contamination. SVE is effective in addressing VOCs and other hazardous air pollutants (HAPs). SVE systems remove volatile contaminants from the subsurface by applying a vacuum to the soil. This vacuum induces the flow of air and contaminants towards extraction wells or vents, where they are then transported to treatment systems for purification.

Applications and benefits. SVE systems are widely used for environmental remediation, brownfield redevelopment and controlling emissions from underground storage tanks. This equipment is commonly employed in industrial environments where the coexistence of oil and water mixtures arises as a consequence of manufacturing processes, found in such facilities as wastewater treatment plants, petroleum refineries and petrochemical plants. In addition to helping sites achieve compliance with stringent environmental regulations, SVE offers several other advantages related to cost and environmental preservation. SVE systems are an especially cost-effective means of remediating contaminated sites, because they can reduce the need for extensive excavation or costly chemical treatment methods. By safely extracting and treating contaminants, SVE systems prevent further damage to soil and groundwater, contributing to overall environmental preservation (Figure 2).

Challenges and considerations. Implementing SVE systems can be an effective method for remediating contaminated soil and groundwater, but it comes with several challenges and considerations. Below are some key factors to keep in mind when planning and executing an SVE project:

Site characterization. Comprehensive site characterization is crucial to understand the nature and extent of contamination, as well as the physical and chemical properties of the soil and groundwater.

Contaminant type and concentration. The type and concentration of contaminants in the soil will influence the design of the SVE system. Some contaminants may be more challenging to remove than others.

Energy consumption. SVE systems can be energy-intensive, especially when dealing with large or deep contamination plumes. It is essential


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FIGURE 1. There are many technologies available to help mitigate the negative impacts of air pollution

FIGURE 2. Soil vapor extraction is an effective method for mitigating soil contamination

to consider the energy costs and environmental impact associated with the operation.

Chemical scrubber systems

Chemical scrubber systems represent another crucial facet of noncombustion clean air technologies, offering a reliable method for removing gaseous pollutants from industrial emissions. These systems pass exhaust gases through a chemical scrubbing solution, which reacts with and neutralizes pollutants. The treated gases are then released into the atmosphere, significantly cleaner and safer.

Applications and benefits. Chemical scrubber systems find applications in a variety of industries, including petrochemicals, pharmaceuticals and metal fabrication. Their benefits include high removal efficiency, safety and simplified environmental compliance. Chemical scrubbers can effectively remove a wide range of gaseous pollutants, making them versatile in addressing diverse emission sources. They are especially useful for capturing hazardous gases, enhancing workplace safety and reducing health risks. Furthermore, compliance with emissions regulations is easier to achieve with chemical scrubbers in place.

Challenges and considerations. One of the primary challenges is the cost associated with designing, purchasing, installing and maintaining a chemical scrubber system. The initial investment may deter some organizations from adopting this technology.

Additionally, chemical scrubber systems often require significant physical space for installation. Space considerations can be a major limitation, especially in existing industrial facilities where retrofitting may be necessary. Finally, while chemical scrubbers can be effective at reducing emissions, they can also have environmental impacts, such as the production and disposal of scrubbing chemicals.

Air strippers

Air strippers play a vital role in treating contaminated groundwater and wastewater, helping to alleviate the burden of waterborne pollutants on the environment. Air strippers transfer volatile contaminants from water into the air. This is achieved using aeration and stripping towers, where contaminated water is exposed to air, allowing volatile compounds to vaporize and be carried away.

Applications and benefits. Air strippers are extensively used in the treatment of groundwater and wastewater. Air strippers excel in removing VOCs from water. Some air-stripping systems can recover and recycle certain chemicals, further contributing to sustainability efforts. Air strippers can be configured to handle various flowrates and pollutant types, making them adaptable to different treatment scenarios.

Challenges and considerations. Implementing an air stripper system can be a complex task, and there are various challenges and factors that must be considered to ensure its successful implementation, such as:

Contaminant types. Air strippers are most effective at removing volatile contaminants. If the target contaminants are non-volatile or have low volatility, alternative treatment methods may be more suitable.

Water chemistry. The pH and chemical composition of the water can affect the performance and longevity of air stripper components. It is crucial to monitor and adjust these parameters as needed.

Operating conditions. Ensure that the air-stripper system operates within its design specifications. Factors such as air-to-water ratios, air pressure and water temperature should be carefully controlled and monitored.

Oil-water separators

In industrial settings, the separation of oil and water is crucial to prevent the release of hydrocarbons into the environment. Oil-water separators are used to achieve this separation efficiently. Oil-water separators employ various techniques, including gravity separation and coalescence, to separate oil from water. As water and oil enter the separator, they undergo a process that allows the oil to rise to the surface, where it can be skimmed off and removed.

Applications and benefits. Oil-water separators are commonly found in many manufacturing sectors, such as automotive, aerospace and other industrial processes. These systems provide environmental protection by preventing oil discharge into water bodies. They also help industries to meet strict environmental regulations governing oil discharge (Figure 3). Furthermore, properly functioning oil-water separators can reduce disposal costs and minimize potential fines.

Challenges and considerations. One of the primary considerations in the deployment of oil-water separators is ensuring that the system complies with all local, state and federal regulations. Regulations may dictate the type of separator required, discharge limits and maintenance requirements. Also, selecting the right materials for the separator is essential. Materials must be compatible with the wastewater stream to be handled. Resistance to corrosion and degradation are also crucial factors in materials selection. Cost is another important consideration. The installation of oil-water separators can be expensive, encompassing expenses for equipment, construction and engineering. It is crucial to evaluate both the initial budget limitations and the potential for longterm cost savings.

Carbon-bed systems

Carbon-bed systems, also known as activated-carbon adsorption systems, are a valuable tool in capturing and removing gaseous pollutants and VOCs from industrial emissions.

These systems utilize activated carbon, a highly porous material with a large surface area, to adsorb pol-

FIGURE 3. There are often strict environmental regulations related to the discharge of oil into water bodies

lutants from exhaust gases. As the gases pass through the carbon bed, pollutants become trapped on the carbon's surface. To learn more about activated carbon, see Introduction to Activated Carbon, *Chem. Eng.*, May 2023, pp. 26–31.

Applications and benefits. Carbon-bed systems are employed in a wide range of industries, including food processing, chemical manufacturing and pharmaceuticals. Their advantages include high efficiency and versatility. Activated carbon has a remarkable adsorption capacity, allowing for the efficient removal of a wide variety of pollutants. Carbon-bed systems can be customized to target specific contaminants, ensuring optimal performance.

Challenges and considerations. Implementing carbon-bed systems for the purpose of air or water purification can be a complex and challenging process. Below are some of the key challenges and considerations to keep in mind when implementing carbon-bed systems:

System design. Designing an effective carbon-bed system requires a thorough understanding of the specific contaminants to be removed and the flowrates involved. The system must be designed to ensure proper contact time between the contaminated air or water and the carbon bed for efficient adsorption.

Carbon selection. Choosing the right type of activated carbon is critical. Different types of carbon have varying adsorption capacities for different contaminants. Consider factors like pore size, surface area and the presence of impurities when selecting the appropriate carbon media for a particular application.

Temperature and humidity. Temperature and humidity levels can affect the adsorption capacity of the carbon bed. Extremes in temperature and humidity should be considered and controlled if necessary.

Fabric filters

Fabric filters, often referred to as dust collectors or baghouses, are integral to the control of particulate-matter emissions from industrial processes, playing a pivotal role in maintaining air quality standards. Baghouses consist of an array of fabric filter bags or cartridges that capture particulate matter as exhaust gases pass through them. The collected particulate matter is periodically removed and disposed of, while clean air is released into the atmosphere.

Applications and benefits. Fabric filters are ubiquitous in industries like cement production, coal-fired power plants and metalworking. Their advantages include high efficiency, cost-effectiveness and ability to effectively achieve compliance with strict regulatory standards governing particulate-matter emissions. Baghouses can achieve extremely high particle-removal efficiencies, reducing airborne pollutants to negligible levels. They are known for their long service life and low maintenance requirements.

Challenges and considerations. Implementing fabric filter systems can be an effective way to control air pollution and remove particulate matter from industrial processes, but there are several challenges and considerations that need to be kept in mind during the operation of the system, described below:

Cost. Fabric filter systems can be expensive to purchase and install. Even beyond the initial investment, they also introduce ongoing operating costs, including energy consumption, maintenance and periodic replacement of filter bags.

Emission monitoring. Many baghouse systems require continuous emission monitoring to ensure that they are meeting regulatory requirements. Implementing and maintaining this monitoring system can require significant effort.

Safety. Baghouse systems can pose safety risks during maintenance and operation. Proper safety procedures, training and equipment are essential to protect workers.

Non-combustion clean air technologies have emerged as indispensable tools in the ongoing battle against air pollution and environmental degradation. Each type of system offers unique solutions to address various sources of pollution in different industrial sectors. In selecting an air pollution control technology, it is crucial to understand the intricate relationship between environmental stewardship and industrial productivity. These technologies can not only ensure compliance with stringent regulations, but also demonstrate a commitment to environmental sustainability. ■

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December 2023; VOL. 130; NO. 12

Economic Indicators

2021 2022 2023

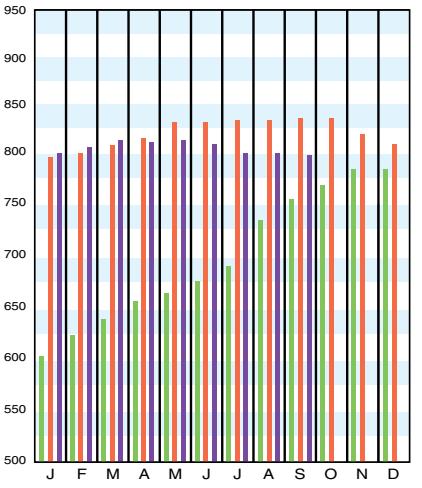
Download the CEPCI two weeks sooner at www.chemengonline.com/pci

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957–59 = 100)	Sept. '23 Prelim.	Aug. '23 Final	Sept. '22 Final
CE Index	793.5	798.7	821.3
Equipment	996.0	1,004.1	1,042.1
Heat exchangers & tanks	812.3	822.2	872.2
Process machinery	1,021.1	1,026.6	1,047.5
Pipe, valves & fittings	1,335.9	1,338.9	1,478.1
Process instruments	561.4	562.4	556.8
Pumps & compressors	1,479.5	1,501.7	1311.6
Electrical equipment	801.6	801.7	784.5
Structural supports & misc.	1,111.7	1,129.2	1,169.8
Construction labor	374.6	373.3	360.9
Buildings	808.4	812.8	813.7
Engineering & supervision	313.3	313.0	311.3

Annual Index:
2015 = 556.8
2016 = 541.7
2017 = 567.5
2018 = 603.1
2019 = 607.5
2020 = 596.2
2021 = 708.8
2022 = 816.0

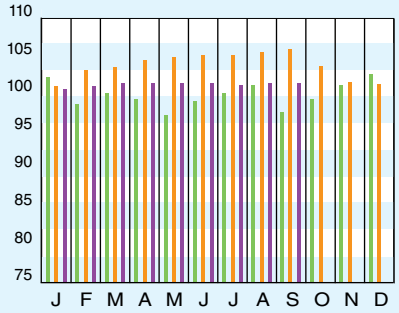
Starting in April 2007, several data series for labor and compressors were converted to accommodate series IDs discontinued by the U.S. Bureau of Labor Statistics (BLS). Starting in March 2018, the data series for chemical industry special machinery was replaced because the series was discontinued by BLS (see *Chem. Eng.*, April 2018, p. 76–77.)



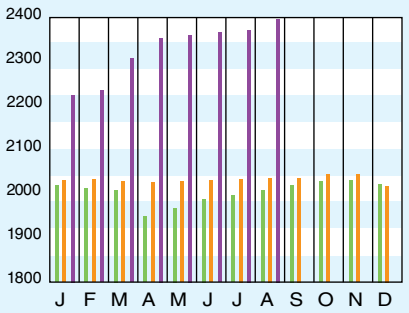
CURRENT BUSINESS INDICATORS

	LATEST		PREVIOUS		YEAR AGO	
CPI output index (2017 = 100)	Sept. '23 =	99.6	Aug. '23 =	98.9	Jul. '23 =	98.7	Sept. '22 =	101.0
CPI value of output, $ billions	Aug. '23 =	2,447.1	Jul. '23 =	2,373.1	Jun. '23 =	2,323.9	Aug. '22 =	2,512.3
CPI operating rate, %	Sept. '23 =	79.1	Aug. '23 =	78.7	Jul. '23 =	78.6	Sept. '22 =	81.2
Producer prices, industrial chemicals (1982 = 100)	Sept. '23 =	307.5	Aug. '23 =	306.7	Jul. '23 =	310.1	Sept. '22 =	348.7
Industrial Production in Manufacturing (2017 =100)*	Sept. '23 =	99.8	Aug. '23 =	99.4	Jul. '23 =	99.5	Sept. '22 =	100.6
Hourly earnings index, chemical & allied products (1992 = 100)	Aug. '23 =	224.7	Jul. '23 =	224.9	Jun. '23 =	222.6	Aug. '22 =	203.0
Productivity index, chemicals & allied products (1992 = 100)	Sept. '23 =	91.7	Aug. '23 =	91.3	Jul. '23 =	91.5	Sept. '22 =	90.7

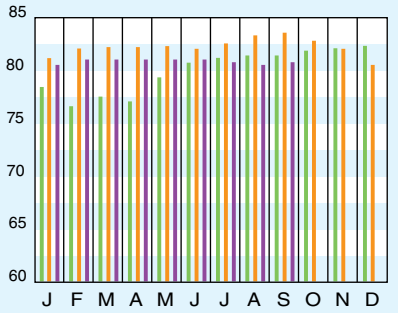
CPI OUTPUT INDEX (2017 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2012 to 2017
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the *CE* Plant Cost Index (CEPCI; top) for September 2023 (the most recent available) fell compared to the August value, reversing the slight increase that was observed from the cycle prior to that. The CEPCI has been fluctuating up and down since the beginning of the year. The September 2023 decrease was driven by the Equipment and Buildings subindices, which both fell, offsetting small increases in the Construction Labor and Engineering & Supervision subindices. The current CEPCI value now sits at 3.4% lower than the corresponding value from September 2022. Meanwhile, the Current Business Indicators (middle) saw an increase in the CPI output index and the CPI operating rate for September 2023.